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Expert Report of
Mark W. Johns, Ph.D., P.G., L.G.

Harris County v. International Paper Company, et al.**, Harris County District Court Case No. 2011-76724**

Dao Van Pho, et al. v. International Paper Company, et al.**, Harris County District Court Case No. 2012-39857**

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Prepared for

Bracewell & Giuliani	Winstead PC	Baker & Hostetler LLP
711 Louisiana, Suite 2300	600 Travis, Suite 1100	1000 Louisiana, Suite 2000
Houston, Texas 77002	Houston, Texas 77002	Houston, Texas 77002

Prepared by

Mark W. Johns, Ph.D., P.G., L.G.
Exponent
15375 SE 30th Place, Suite 250
Bellevue, WA 98007

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Acronyms and Abbreviations

2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-*p*-dioxin
Big Star	Big Star Barge & Boat Company
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rating Maps
HEC-RAS	Hydrologic Engineering Center River Analysis System model
HSC	Houston Ship Channel
I-10	Interstate Highway 10
Impoundments	impoundments north of the I-10 Highway
MIMC	McGinnes Industrial Maintenance Corporation
NOAA	National Oceanic and Atmospheric Administration
OCDD	octachlorodibenzo-*p*-dioxin
OCDF	octachlorodibenzofuran
PCDD	polychlorinated dibenzo-*p*-dioxin
PCDF	polychlorinated dibenzofuran
PSD	particle-size distribution
RI/FS	remedial investigation and feasibility study
the Site	San Jacinto River Waste Pits Superfund Site
SJRWP	San Jacinto River Waste Pits
TCDD	tetrachlorodibenzo-*p*-dioxin
TCDF	tetrachlorodibenzofuran
TCEQ	Texas Commission on Environmental Quality
TCRA	Time Critical Removal Action
TDOH	Texas Department of Health
TEF	toxicity equivalent factor
TEQ	toxicity equivalent
TEQ_{DF}	TEQ concentration calculated using only dioxin and furan congeners
TMDL	total maximum daily load
TPWD	Texas Parks and Wildlife Department
USGS	U.S. Geological Survey
WASP	Water Quality Analysis Simulation Program

1 Introduction

This report has been prepared on behalf of International Paper Company, McGinnes Industrial Maintenance Corporation (MIMC), Waste Management of Texas, Inc., and Waste Management, Inc. This report presents my current opinions in the matters of *Harris County v. International Paper Company, et al.*, Harris County District Court Case No. 2011-76724; *Dao Van Pho, et al. v. International Paper Company, et al.*, Harris County District Court Case No. 2012-39857; and *Jim Harpster, et al. v. International Paper Company, et al.*, Harris County District Court Case No 2012-66308.

2 Qualifications and Information Considered

I am a Principal Scientist in the Environmental and Earth Sciences Practice at Exponent. Exponent is a scientific and engineering consulting firm headquartered in Menlo Park, California. I am based in the Bellevue, Washington, office. I have held the position of Principal Scientist at Exponent since 2003. As a Principal of the firm, I provide program management and technical consulting services. I have evaluated sediment dioxin issues at numerous sites including pulp and paper mills. My experience includes remedial investigation and feasibility study (RI/FS) analysis; cost estimation; environmental litigation technical support; environmental transport and fate; site investigation, remediation, and closure; contaminated site redevelopment; waste management; remedial performance evaluation; and site assessments, compliance audits, and restoration. I specialize in the investigation, management, remediation, recycling, disposal, cleanup, and closure of sites and facilities that manage or are affected by hazardous and potentially hazardous materials, and other materials regulated under the Comprehensive Environmental Response, Compensation and Liability Act of 1980 and the various state laws and regulations.

I have a Ph.D. in Geological Oceanography from Texas A&M University, earned in 1985. I am a licensed Geologist/Hydrogeologist in the state of Washington (LG-1262), a licensed Professional Geoscientist in the state of Texas (No. 3221), and a registered Professional Geologist in the state of Wyoming (PG-3237). I have also been registered with the Washington Department of Ecology Underground Storage Tank Program since 1990. My training includes the following: 40-Hour Hazardous Waste Operations and Emergency Response – Level A, HAZWOPER, 1986; 8-Hour HAZWOPER Managers and Supervisor Training; Advanced Health and Safety for Hazardous Waste Site Management, 1987; and 8-Hour OSHA Annual Refresher.

I have more than 25 years of experience in the field of environmental science. My *curriculum vitae*, including a list of publications, is included as Exhibit A.

I reserve the right to supplement and modify this report as and when additional information becomes available to me, or if I am asked to address additional issues. In addition, I respectfully reserve the right to supplement my opinions in light of any new information that becomes available or additional documents that may be reviewed, as well as information that may become available from other sources.

Exponent is being compensated at the rate of $345 per hour for my work related to this matter. No part of this compensation is contingent on the outcome of this matter.

In addition to my education, experience, and training, I reviewed the documents listed in Exhibit B. I have relied on and/or reviewed both the documents provided by Baker & Hostetler LLP, Winstead PC, and Bracewell & Giuliani LLP and documents obtained by Exponent.

3 Background

In 1965 and 1966, pulp and paper mill wastes were reportedly transported by barge from the Champion Paper Inc. paper mill in Pasadena, Texas, and deposited in impoundments north of Interstate Highway 10 (I-10) (Impoundments) (Integral and Anchor QEA 2013c,d). The Impoundments are located on the western side of the San Jacinto River, in Harris County, Texas, north of I-10 (Figures 1 and 2). The 1966 photograph shows that the Impoundments were originally surrounded by land.

Historical records reflect that the Impoundments were constructed in 1965 by forming berms, just north of what was then Texas State Highway 73 (now I-10), to the west of the main river channel. The Impoundments were divided by a central berm running lengthwise (north to south) through the middle. The Impoundments were connected with a drain line to allow the flow of excess water (including rain water) from the western pond to the eastern pond (Thompson 1966) The liquid portion was then pumped back to the barge and returned to the Champion Paper mill for treatment (Thompson 1966).

The remedial investigation noted that estuarine riparian vegetation lined the upland area of the Impoundments and included broadleaf cattail, saltmeadow cordgrass, saltmarsh aster, and marsh elder. There is evidence of a layer of clay-like soil over the western Impoundment as noted in boring logs that were collected in this area for the groundwater investigation (Anchor QEA2011a). As early as 1966, grass was growing on the Impoundments (Thompson 1966). The vegetation likely acted to stabilize the surface of the Impoundments. This vegetation was removed as a result of the Time Critical Removal Action (TCRA; Integral and Anchor QEA 2012c,d).

The Impoundments underwent a TCRA as part of Administrative Order on Consent with the U.S. Environmental Protection Agency (EPA) (Docket No. 06-12-10, May 2010) that was completed in July 2011 (Anchor QEA 2011a, Integral Anchor QEA 2013c). Construction of the TCRA included a substantial cap. The cap consisted of geomembrane and geotextile layers covered by approximately 59,000 tons of rock to produce an armored cap that ranged in thickness from12 to 24 in. (Anchor QEA 2011b). The design included a thickened cap edge to reduce the potential for undercutting of the cap by scour forces (Anchor QEA 2013).

4 Opinions

4.1 Opinion: The settled solids from the Champion Paper process that were placed in the Impoundments have very low hydraulic conductivities, harden quickly, and contain dioxins and furans that have not been transported to groundwater.

The Impoundments received at least four evaluations in connection with their construction, design and operation. The first two were from the Harris County Health Unit[1], and the third and fourth were from the Texas Department of Health (TDOH) and the Texas Water Pollution Control Board, respectively.

The disposal site was visited by Dr. Quebedeaux of the Harris County Health Unit on May 25, 1965 (Quebedeaux 1965a). He later characterized the Impoundments in a letter to Burma Engineering as (Quebedeaux 1965b):

> "The location of the proposed spoil pond, which is located on the west bank of the San Jacinto River just north of the Highway 73 bridge, seems to be ideal for the purpose for which you intend to use it. This is particularly so since the bottom and sides, or dikes, are composed of clay, which should render it practically impossible for seepage to escape and enter into the San Jacinto River."

On April 22, 1966, TDOH made an investigation of the waste disposal practices associated with the Impoundments. At that time, the investigators reviewed the practice of disposal of settled solids that began in 1965.

The TDOH described the properties of the waste materials as neutral in pH and primarily fibrous. The material solidified rapidly and after a "short time" the material would solidify to a state such that water would not penetrate it, it could stand to a vertical cut and "…the dried material resembled a cheaper grade of cardboard – such as used in egg cartons…" (Thompson 1966). It was further noted "…that grass can be started on the dry material and that it would spread rapidly, thus further cutting off water."

During this 1966 visit, the pond berms on the filled pond (Pond #1 to the west) were noted to be in "good shape, with possible slight seepage." It was further noted that the material in the ponds solidifies quickly and "…would pose no danger of pollution from seepage" (Thompson 1966). Excess water flowed from the western pond into the eastern pond where it was pumped to barges and returned to the Champion Mill (Figure 3 from Thompson 1966). This was accomplished by the installation of a drain between the western and eastern Impoundments (see

[1] Letters from W.A. Quebedeaux, Jr., to Burma Engineering, May 25 and June 11, 1965.

Figure 3). Because the ponds were dewatered during loading, the hydraulic gradients were low and could not have reached the levels as suggested by Plaintiffs' expert Bedient (2013a).

During the 1966 TDOH visit, a map was prepared showing that the ponds were surrounded by land and the report noted that the area was not subject to flooding (Figure 3). As noted in the report:

> "The two new ponds [the ponds north of Highway 73] are connected with a drain line to allow the flow of excess water (including rain water) from pond #1 to pond #2 where it collects near the barge unloading area. At the present time, this water is pumped back into the barges and returned to the Champion Paper plant where it is passed through the last settling ponds and discharged to the Channel with the rest of the plant effluent."

As noted above, the properties of the waste materials were described as neutral in pH and primarily fibrous. The process of paper making involves physically or chemically breaking wood to cellulose fibers that are characteristically small, slender tubes with pointed ends. Pulp is a water slurry of limp fibers that has a gelatinous texture (Carter et al. 1968). The pulp contains a natural glue (lignins). Consequently, the sludge material solidified rapidly and after a "short time" the material would solidify to a state that "…water would not penetrate it" and "…that a vertical wall can be cut in the ponds while removed it and that the wall will stand" (Thompson 1966). The fibrous organic nature of the materials was further analyzed during the recent groundwater investigation at the Impoundments (Anchor QEA and Integral 2011a). Three samples were collected from approximately 0–3 ft below grade for hydraulic conductivity testing from within the western Impoundment (see Table 1 and see Anchor QEA and Integral 2011a). As noted in the report, these materials are typically described as having clay-like texture[2] and their hydraulic conductivities correspond to the finer end point of silt and coarser end point of unweathered marine clay (Freeze and Cherry 1979). As the pulp is dewatered and formed against the berm walls it may have acted to further reduce any migration through the berms.

Several studies have indicated that groundwater contamination is not an issue for the Impoundments (Integral and Anchor QEA 2012a,b). The Preliminary Site Characterization report states:

> "A pathway resulting in the transfer of dioxins and furans from the waste in impoundments north of I-10 into the groundwater was not presented in the original Site CSM [*Conceptual Site Model*], because it was recognized that there were no exposure pathways from groundwater to any receptors. Nevertheless, a groundwater study was conducted under the RI with three well pairs surrounding the western cell of the northern impoundments, and one well screened within the wastes. As described in Section 6.2.4, sampling results from these wells

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[2] MIMC made a presentation to the Texas Water Pollution Control Board on August 11, 1966 (TWPCB 1966). In that meeting, a Brown and Root, Incorporated engineer, Mr. Millwee, described the Champion Paper Mill waste as containing clays and paper fibers. He further went on to describe the Impoundments saying: "There have been no releases from that area."

> demonstrate that both shallow alluvial and deep groundwater resources are not contaminated with dioxins and furans, or other COPCs, and results of the hydraulic conductivity testing indicate that the wastes have low permeability. Results of the groundwater study confirm that, there is no exposure pathway potentially leading to exposures to waste-related dioxins and furans from the north impoundment area in shallow alluvial groundwater and deep groundwater" (Integral and AnchorQEA 2012a,b, p. 6-75)."

In addition, the Public Health Assessment prepared by the Texas Department of State Health Services and the Agency for Toxic Substances and Disease Registry concluded that exposures to groundwater do not exist near the Impoundments and "…were not expected to contribute to people's overall risks" (TDSHS 2012).

It is also appropriate to consider the potential for water flow through the berms from the Impoundments. To do such an analysis, representative porosities, hydraulic conductivities, and hydraulic gradient are required (see Table 1). As noted above, the hydraulic gradient during the time of pond filling was likely similar to the existing groundwater gradient because of the installed drainage system. Anchor QEA discusses the groundwater well locations and potentiometric surface near the Impoundments and a gradient of 1.75×10^{-3} ft/ft can be inferred from Figures 4 and 5 (Integral and Anchor QEA 2012a,b):

> "Water level data indicate that groundwater flows in the alluvium are approximately congruent with localized surface topography (Figure 6-7), and discharge as expected generally to the San Jacinto River (periods of high tides or flood conditions may temporarily and locally reverse shallow groundwater flow gradients). This flow direction is expected because the water table normally mimics topography in a subdued manner in unconsolidated materials (Freeze and Cherry, 1979)."

In summary, the groundwater immediately below the Impoundments does not contain dioxins and the berms of the Impoundments were constructed from the same clay materials that were shown to be highly impermeable during the remedial investigation. During the remedial investigation, these materials were shown to have very low hydraulic conductivity, consistent with Dr. Quebedeaux's observations (1965a,b). In addition, the waste materials in the Impoundments had similar, very low hydraulic conductivity. A groundwater investigation was conducted, which confirmed that groundwater below the Impoundments was not impacted by dioxins and furans (i.e., 2,3,7,8-TCDD was not detected in any of the six monitoring wells) after more than 40 years of being in place.

4.2 Opinion: The Impoundment berms have low hydraulic conductivities.

Available historic documentation regarding the construction of the berms indicates that they were composed of clay (Quebedeaux 1965). As discussed above and below, this is consistent with the findings from the boring logs and groundwater investigation results (Anchor QEA and Integral (Anchor QEA and Integral 2012a,b; 2011a,b). If the berms had been constructed with sand as assumed by Bedient, they would not have had the strength to withstand the rain and potential flooding conditions in this area for over 40 years. Sands are non-cohesive materials. Moreover, if onsite soil and sediments had been used, the berms would be much more impermeable than suggested by Bedient (2013b). The soils and sediments surrounding the Impoundments have been evaluated and sampled extensively. The 1970 Subsurface Exploration San Jacinto River I.H.-10 report provides logs for borings that were installed near the Impoundments to interpret soil conditions and specifically to determine the commercial suitability and recovery potential of any sand strata encountered north of I-10 (HIT 1970–2004; Figure 6). Two borings (B4 and B7) were installed in the area of the Impoundments. Boring B-4 encountered gray clay with light gray, sandy layers to a depth of 8 ft. Boring B-7 encountered gray clay to a depth of 7 ft. These borings were installed on land before the dredging near the Impoundments began.

Additionally, boring logs for wells SJMWD01 and SJMWD03 that were installed during the groundwater investigation are shown in Figure 7. The well boring logs describe the materials as silt and clay to a depth of 8 ft at SJWMD01 and silt and fine sand to a depth of 5 ft with clay from 5 ft to 12 ft at SJMWD03 (Anchor QEA and Integral 2011a,b).

Numerous sediment samples have been collected from across the Site. Samples collected from beach areas shown in Figure 8 have particle-size distributions (PSDs) shown in Figure 9. In addition, median grain-size data from 169 locations in the study area were collected by Anchor QEA (2012a) as shown in Figure 10. Table 2 lists the median grain sizes for sediment samples (beach areas and the minimum, median, and maximum of those from the 169 samples collected in the area around the Impoundments). Classifications are presented for the distributions in the beach areas from the U.S. Department of Agriculture textural classification shown in Figure 11 (Das 1994, Fig. 3-1) and the Wentworth Aggregate Class for the maximum, median, and minimum single sizes reported for the remaining samples (Holtz and Kovacs 1981, Fig. 2-3; Wentworth 1922).

The shallow-core data in Table 1 correspond to hydraulic conductivities for the finer end of silt to the coarser end of unweathered marine clay and are representative of the waste material described as having a clay-like texture. Thus the hydraulic conductivity of these berm materials would be very low (Table 1). Overall, calculated movement of liquids, if any, through the berms would be orders of magnitude slower than those calculated by Bedient (2013a). Bedient assumed that the berms were constructed with sand and assumed high hydraulic conductivity. In addition, he assumed that there was 7 ft of head in the Impoundments and that they were 21 ft wide (Bedient 2013a). These assumptions drive the high flow velocities that he calculated. The Impoundment berms were made of clay, filled at a slow barge-by-barge rate, and decanted to the east side. Therefore, the hydraulic gradient could not have been as high as Bedient suggests (Bedient 2013a,b).

In conclusion, it is important to note that Quebedeaux observed the berms during his site visit and found them to be constructed from clay (1965a,b). He said:

> "The location of the proposed spoil pond, which is located on the west bank of the San Jacinto River just north of the Highway 73 bridge, seems to be ideal for the

> purpose for which you intend to use it. This is particularly so since the bottom and sides, or dikes, are composed of clay, which should render it practically impossible for seepage to escape and enter into the San Jacinto River."

4.3 Opinion: Dredging activity has undercut and cut into the berms and waste materials in the Impoundments and resulted in transport of settled solids containing dioxins and furans to the sand mining facility.

At the time of construction of the Impoundments, the San Jacinto River was some distance away (Thompson 1966). Dredging was conducted in the vicinity of the Impoundments for many years. Several companies have been responsible for those activities, including Big Star Barge & Boat Company (Big Star), Houston International Terminal, Inc. (HIT) and MegaSand Enterprises, Inc. (Integral and Anchor QEA 2012a,b).

Aerial photographs from 2002 with bathymetry from 2009 show the physical impacts of dredging and decanting activities in these areas (Figures 12 and 13). The dredged materials appear to have been removed from the areas surrounding the Impoundments and transported to the dredge material drainage/decant system located on the Big Star property west of the Impoundments (Anchor QEA 2011a).

Anchor QEA (2011a) provided the bathymetric survey data from the 2009 U.S. Army Corps of Engineers overlain on a 2002 aerial photograph demonstrating the impact of dredging in the areas to the east, north, and west of the Impoundments (Figure 13).

The combination of the aerial photograph and bathymetry shows the impact of dredging immediately adjacent and into the northwest corner of the Impoundment berm. As a comparison to the original configuration, Anchor QEA (2011a) also provided a side-by-side comparison of aerial photographs from 1966 and 2002 (Figure 14). This extensive sand mining in the area was also noted by Koenig (2009 see Figure 15).

By 2009, the edge of the northern berms appears degraded (Figure 16). This illustrates the degree to which the flow regime was modified due to dredging to the north of the Impoundments (Anchor QEA 2011a, see Figure 7).

The soil sampling and analysis plan also discusses the impact of dredging, noting:

> "Based upon review of U.S. Army Corps of Engineers (USACE) approved dredging permits, dredging by third parties has occurred in the vicinity of the perimeter berm at the northwest corner of the impoundments that are north of I-10. Interpretation of historical aerial photographs suggests that the sand mining operation and processing of related sediments extended to the upland area to the west of the northern impoundments, potentially affecting soils in that upland area."

An additional impact that resulted from these dredging activities included redistribution of sediments containing paper mill waste and dioxin in the area of the sand separation facility located on the Big Star property to the west of the Impoundment. Mapped dioxin and furan concentrations (as toxicity equivalents, or TEQs, described later) and the fingerprinting of surface sediment clearly demonstrate this situation (Figure 17) (see Anchor QEA 2011a; Integral and Anchor QEA 2013c,d).

It is apparent that dredging operations were conducted within the area of the Impoundments. These dredging activities removed the sediments that surrounded the Impoundments in 1965 when it was constructed and created a new river channel directly to the north of the Impoundments. This is a significant change in the flow regime in this area. At the time of construction, the Impoundments were surrounded by land. Later, dredging activities cut into the Impoundment berms and containment cells. This resulted in physical damage to the Impoundments and physical redistribution of paper mill wastes containing dioxin to the Big Star property as a direct result of dredging activities into the Impoundments.

In addition, it appears that an additional flow channel with higher velocity currents was created adjacent to the Impoundment berms as a result of the dredging operation.

Aerial photographs and review of the bathymetric and chemical data show that dredging has impacted the northern side of the Impoundments. Scalloped shorelines and steep underwater escarpments were produced by dredging and encroached on the Impoundments. The northern edge of the Impoundments was undermined by dredging activities. This resulted in physical redistribution of paper mill wastes containing dioxins to the Big Star property where they subsequently were distributed in the adjacent sediments (Integral and Anchor QEA 2012a,b).

4.4 Opinion: Changes in the river morphology have impacted the Impoundments through flooding and scouring.

The San Jacinto River system has been impacted by damming of the river, subsidence, and sand mining over the last several decades. The river was dammed in 1953, and subsequently, extensive sand mining occurred in areas upriver of the Impoundments. In the early 1970s, the Texas Parks and Wildlife Department (TPWD) put a moratorium on sand mining (Singleton 1970; Marsh 1971), but these operations continued or had resumed in the 1990s. During this period, the industries and the population in the area grew rapidly. These industries required significant water for operations. This resulted in significant drawdown of the aquifer and land subsidence in the area. The following sections provide a brief summary of the changes in the river and the impacts they had on the Impoundments.

4.4.1 Subsidence

According to Bedient (2013a,b), subsidence in the area of the Impoundments was 6 ft from 1906 to 1978 and approximately 0.5 ft from 1973 to 2010. The center of subsidence is east-southeast of Houston at Pasadena, Texas. The U.S. Geological Survey (USGS) has reported that more than 9 ft (2.7 m) and possibly as much as 10 ft (3.0 m) of subsidence has occurred (Gabrysch

1976, 1984). This is attributed to the lowering of the pressure heads due to pumping of water and oil in the Houston-Galveston areas. TPWD noted that the Impoundments were constructed about 10 ft above the river and have subsided "about 10-12 feet since the pits were closed" (Sipocz 2005).

4.4.2 River Morphology

The morphology of the San Jacinto River prior to 1953 was not impacted by flood controls. The river was free-flowing and relatively uncontrolled. This resulted in annual flood events due to monsoonal rains and storms. Historical aerial photographs show that the river was fairly well incised with clearly defined banks (compare Figures 18 and 19). In 1954, the river was dammed and Lake Houston was created when the City of Houston built the dam to create a reservoir to replace the smaller Sheldon Lake, which was previously the primary source of water for the city (see Figure 20).

Downstream of Lake Houston, the San Jacinto River then became a much lower energy, depositional environment given the flow control of the dam. Annual flooding decreased resulting in a lower energy environment. The former annual floods no longer scoured the riverbed and portions of the river, particularly near the I-10 overcrossing. By 1978, the river channel became filled with sediment, resulting in a broad (up to 4,000 ft wide) river floodplain (see Figure 21). At the same time subsidence in the region compounded the situation. This resulted in regional riverbed characteristics that included a shallow, broad, low-energy riverine floodplain requiring dredging to maintain navigation (Figure 22).

Several figures within the Preliminary Site Characterization Report indicate that the Impoundment area from the 2009 and 2010 surveys was at an average elevation of about 2 ft (NAVD88) with the highest points around 8 ft (Integral and Anchor QEA, 2012a,b, Figs. 5-11, 6-5, 6-6, and 6-7).

In order to evaluate the potential impacts of floods near the Impoundments, the Federal Emergency Management Agency's Flood Insurance Rating Maps were reviewed. These maps are developed using the U.S. Army Corps of Engineers' Hydrologic Engineering Center River Analysis System model (HEC-RAS). This modeling produces tiled maps like Figure 23 that show the base-flood elevation (turquoise dashed curve), flooding zones (shaded and hatched regions), and various river transects (transect A is highlighted by the dashed orange curve).

The HEC-RAS model results are presented at various river transects and indicate the magnitude of various flood events. As shown on Figure 24, the depths of the 10-, 50-, 100-, and 500-year flood events are 6.1, 11.7, 13.3, and 18.4 ft, respectively, at the Impoundments. This map shows the Impoundments to now be within the floodplain.

4.4.3 Flood Events

Flood event data for the Impoundments was collected from the San Jacinto River at a location upriver from the Impoundments at the Crosby Highway Bridge between Barrett and Sheldon, Texas. USGS and the National Oceanic and Atmospheric Administration (NOAA) measure flood stages at that location.[3] NOAA (2013) considers 8 ft the "Action Stage," flooding begins at a river stage of 10 ft, becomes "Moderate" at 13 ft, and "Major" in excess of 15 ft. Using these definitions, the river has flooded 25 times since 1929 as listed in Table 3(exceeding the Action Stage 27 times). Twenty-three of the flood events (25 exceeding the Action Stage) occurred after the construction of the Impoundments. Anchor QEA (2012a, p. 24) note that a high-flow event resulting in average river flow velocities of up to 2.5 ft/s occurred when the river flow rate was 21,000 ft^3/s. Using data from NOAA and the USGS to construct a hydrograph for the San Jacinto River results in a best fit of the river stage, *H*, as a function of flow rate, *Q*, of:

$$Q = 616H^{1.813}. \tag{1}$$

The 21,000-ft^3/d flow results in a river stage of H = 7 ft. The NOAA (2013) hydrograph indicates a stage of H = 7.42 ft at 21,000 ft^3/s flow. This analysis suggests that river flow velocities have likely exceeded 2.5 ft/s approximately 25 times since the Impoundments have been present.

Anchor QEA (2012a) prepared a detailed sediment and contaminant fate and transport model. In its report regarding the model, Anchor QEA noted that:

> "During low-flow conditions (i.e., current velocities dominated by tidal effects), maximum current velocities were about 1 foot per second, with typical current velocities of 0.5 foot per second or less during most of the tidal cycle. A high-flow event (maximum flow rate in the river of about 20,000 cfs) occurred during the first week of July 2010. Maximum current velocities during this high-flow event ranged between about 2 and 2.5 feet per second."

Hence, flow velocities in the San Jacinto River due to tidal rise and fall and river flow are fairly low—typically less than 1 ft/s. Only under high-flow events do velocities exceed 2 ft/s.

4.4.4 Permissible Velocities

Permissible velocities refer to the maximum flow velocities that can exist without causing erosion of bed sediments The maximum permissible velocities are not steadfast, as old channels typically can sustain higher velocities before erosion occurs (Chow, 1959). If the near-bed flow velocity exceeds the permissible velocity, then the sediments have the potential to erode. It is important to note that these permissible velocities are determined using the assumption that the soils are non-cohesive. Non-cohesive sediments are primarily sand- and gravel-sized material. It is noted that sediments in the beach areas and from most of the 169 samples collected in the San Jacinto River in the vicinity of the Impoundments exhibit cohesive properties. Even the sediment with the largest maximum d_{50} (0.210 mm) is a fine sand that likely contains a significant fraction (>10%) of claylike particles thereby imparting cohesive properties. Figure 25 is a plot relating permissible velocities to grain sizes.

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[3] Flood stages are available at latitude 29.876111°N and longitude 95.093611°W[3] from both NOAA (2013) since 1929 and USGS (2013) since 1992.

Sediments can be both cohesive and non-cohesive. As discussed earlier, cohesive sediments are composed primarily of clay-sized and silt-sized particles, mixed with organic matter, and sometimes, quantities of fine sand. van Rijn (1993) notes that if the clay fraction in a sediment mixture is greater than 0.10, then the mixture exhibits the characteristics of cohesive sediments. Non-cohesive sediments are primarily sand and gravel-sized material. Also, vegetated channels and floodplains retard flow, increasing the depth of flow and decreasing velocities. This is due to an increase in the flow resistance (Manning's roughness coefficient). This not only enhances the deposition of sediments in suspension but also decreases the potential for erosion of bed sediments because the bed shear stresses induced at the sediment-water interface are lower.

Based on the examination of the PSD data, it is evident that the bed sediments are not only non-uniform but also contain fractions of fine-grained sediments that would cause the sediment mixture to exhibit the properties of cohesive sediments. Resistance to erosion depends upon the sediment type and mineralogy, pore and eroding fluid concentrations, the time history of deposition (i.e., whether the sediments are recently deposited, partially consolidated, or part of a more dense bed), and chemical and biological processes (Van Rijn 1993). The resuspension behavior of cohesive sediments is different from non-cohesive sediments. First, the resuspension potential is limited to a maximum amount for any given bed shear stress. Second, cohesive sediments consolidate with time such that the strength of the bed sediments increases with depth below the sediment-water interface (Sandford 2008). Thus, a larger bed shear stress is required to resuspend these sediments.

According to Chow (1959, Table 7-3), noncolloidal sandy loam has a maximum permissible velocity of 1.75 ft/s for clear water and 2.50 ft/s for water transporting colloidal silts. Given that high flow events result in maximum current velocities of 2.5 ft/s and that these flows contain significant sediment concentrations of 100 to 1,000 mg/L (Anchor QEA, 2012a, Fig. 4-15), the permissible velocity is closer to 2.5 ft/s suggesting that erosion of beach area sediments is minimal except under the highest of flows in the river. Similarly, for fine sands, Chow (1959, Table 7-3) notes maximum permissible velocities of 1.50 ft/s for clear water and 2.50 ft/s for water transporting colloidal silts. From Figure 25, permissible velocities for very fine sand (0.072 mm) and silt (0.004 mm) are 0.7 and 0.5 ft/s, respectively. It is important to note, however, that these estimates of permissible velocity do not include cohesive effects. Because these sediments likely exhibit cohesive properties, the maximum permissible velocities are likely significantly higher.

4.4.5 Scour

As a result of the dredging of the berms and the modified flow regime to the north of the Impoundments, the berms were degraded. In this condition, the river was in contact with the berms. This illustrates the degree to which the flow regime was modified due to dredging to the north of the Impoundments (Anchor QEA 2011a, Figure 16). Now that the San Jacinto River abuts the Impoundments, erosion and scour is possible during certain flood events (Integral and Anchor QEA 2013c,d).

This analysis leads to the conclusion that sediment materials might erode and have the potential to be transported from the dredge impacted Impoundments when the San Jacinto River achieves the “Action Stage” (a depth/stage greater than 8 ft). The action stage would have occurred, at most, 25 times since the installation of the Impoundments and 10 times since the mid-1990s through early 2008 (Table 3). After the berms were impacted by dredging, erosion could have occurred because the following conditions existed:

1. Analysis of beach area sediments indicate that they are mostly sandy loams
2. Sandy loam material has a maximum permissible (sediment-laden) velocity of 2.5 ft/s (Chow 1959, Table 7-3) and it will potentially erode under higher velocities
3. Measured velocities in the San Jacinto River can be up to 2.5 ft/s when the flow rate is 21,000 ft^3/s (Anchor QEA 2012a)
4. The river hydrograph indicates that the stage is 7.42 ft at a flow rate of 21,000 ft^3/s (Anchor QEA 2102a)

4.5 Opinion: There are many sources of dioxins and furans in the San Jacinto River and Houston Ship Channel with TEQs and 2,3,7,8-TCDD concentrations higher than those in sediments near the Impoundments.

The presence of dioxins and furans has been documented in “…practically all media including air, soil, meat, milk, fish, vegetation, and biological samples” (Travis and Hattemer-Fey, 1991). This is a result of aerial dispersion deposition from combustion sources such as vehicle and ship exhaust, waste incineration, trash burning, forest and brush fires, etc. Dioxins and furans are also common as the by-product of the production of chlorinated organic compounds such as herbicides and wood preservatives (Shields et al. 2006). There are literature reviews and compilations on the sources of dioxins and furans (e.g., Fiedler et al. 1996; Rappe 1994; U.S. EPA 1997, 2000, 2003, 2005).

There are many industrial sources of dioxin and furans to the San Jacinto River, Houston Ship Channel (HSC), and Galveston Bay. As early as the 1980s, sampling in the San Jacinto River and areas upstream noted the presence of dioxins and numerous potential sources (U.S. EPA 1987). In 2005, EPA updated its “Inventory of sources and environmental releases of dioxin-like compounds in the United States” through 2000 (U.S. EPA 2005). This document is a comprehensive literature review containing over 800 references cited.

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are halogenated aromatic compounds that have been widely found in the environment. The PCDDs include 75 congeners and PCDFs include 135 different congeners (Table 4). Only 7 out of the 75 PCDD congeners and 10 of the 135 PCDF congeners have been identified as having dioxin-like toxicity (U.S. EPA 2005; Shields 2006; Rifai 2007).

PCDD/PCDF homologues refer to compounds with the same number of chlorine atoms. PCDDs and PCDFs have a triple-ring structure that consists of two benzene rings connected by either one or two oxygen molecules (PCDDs and PCDFs respectively) (Figure 26). The term “congener” refers to any individual PCDD/PCDF compound, regardless of homologue class (Shields et al. 2006).

PCDD and PCDF concentrations are often expressed as 2,3,7,8-TCDD TEQ by multiplying the concentration of each of the 17 2,3,7,8-substituted congeners by its respective toxic equivalent factor toxicity equivalent factor (TEF; Table 5).

Chemical fingerprinting, as discussed below, is one tool that is used to identify or rule out potential sources of dioxin. Understanding the physical and chemical parameters associated with dioxin and furans is important but it is imperative to understand the fate and transport mechanisms that drive the movement of source material to a receptor in order to conclude that a fingerprint is the result of a source.

Dioxins are highly hydrophobic compounds. They have very low water solubility (the ability to dissolve into water) and prefer to associate with organic carbon (lipophilic). Organic carbon naturally occurs in sediments from the decay of plant and animal tissues. Organic carbon also occurs in living tissue and is in the paper mill waste material at elevated concentrations. It is important to note that solubility decreases with increasing chlorine substitutions. Similarly, the vapor pressure for these compounds is very low (the ability to evaporate into the air) and these compounds tend to attach to particles in the air. The vapor pressure decreases as more chlorine substitution occurs.

The HSC and vicinity was extensively studied by the Texas Commission on Environmental Quality (TCEQ) during the total maximum daily load (TMDL) and other studies since the early 1990s (UOH and PWI 2006, 2009). In 1990, TDOH issued a seafood consumption advisory for catfish and blue crabs in locations that included the upper portion of Galveston Bay and the HSC (Rifai 2006b). One of the early precursor studies was the HSC Toxicity Study (ENSR 1995). This study was undertaken by the City of Houston. This study was implemented under Consent Decree (H-91-3072) with EPA. The Consent Decree was administered in response to the alleged violations of the National Pollutant Discharge Elimination System permit No. TX0046884 (ENSR 1995). The reason for implementation of the program was the discharge of pollutants and contaminants from the City’s Northside Wastewater Treatment Plant and 11th Street Lift Station. The study was designed to improve the knowledge of the system and the ability to manage water quality.

4.5.1 Houston Ship Channel Toxicity Study (ENSR 1995)

The study reportedly collected and analyzed chemical data for sediment, water, and fish tissue. As part of the summer low-flow survey in August 1993, sediment samples were collected from 10 stations and analyzed for all 17 of the 2,3,7,8-substituted dioxin and furan congeners as well as the total homologues. On a subsequent trip in May 1994, five stations were resampled and one new station was sampled. Sediment was collected during the summer low-flow survey from Stations 1, 7, 8, 9, 10, 16, 17, 2SA, and 33. On the second sampling trip samples were collected from Stations 7, 9, 10, 15, 16, 17A, and 26A (ENSR 1995). ENSR reported the TEQs according to the international TEFs adopted in 1989.

Sample stations are shown on Figure 27. Sediment data for dioxins and furans were analyzed for a smaller group of locations shown in Table 6.

These data were discussed by Plaintiffs' expert Dr. Sass on page 40 of his report (Sass 2013). He noted that the study reported "…unexplained, high concentrations of dioxins in sediment samples in the vicinity of the San Jacinto River where it flows under the I-10 bridge." He was referring to Station 009 that is located above the I-10 bridge and *upriver* of the Impoundments in the middle section of the San Jacinto River.

The ENSR (1995) report explains the dioxin/furan concentration as analyzed by the study in a somewhat different light. First, ENSR graphically showed the locations of the two sampling events on a figure with TEQs calculated using zero for concentrations that were below detection limits (Figure 28 from ENSR 1995).

This figure clearly shows several locations with much higher TEQ concentrations in the HSC. The report summarizes the stations with the highest TEQ concentrations (ENSR 1995, page 46):

> "TEQs of 2,3,7,8·TCDD ranged from 0.57 to 409 ng/kg. The lowest TEQ was found at Station 10 (San Jacinto River at Rio Villa), and the highest concentration was found at Station 15 (Patrick Bayou). The second and third highest concentrations were found at Stations 16 (HSC at the mouth of Patrick Bayou) and 26A (HSC downstream of confluence with Vince Bayou). These values are shown graphically on Figure 4.2·17."

Furthermore, ENSR noted that Stations 15, 16, 17A, and 26A had the highest TEQs and were the "most toxic sediments." These stations had maximum TEQ (non-detections at zero) concentrations of 409, 158, 62.7 and 130 ng/kg, respectively. These values are 1.4 to 8.9 times higher than found at Station 009 (46.1 ng/kg).

ENSR (1995) noted other source areas for the highest concentrations of 2,3,7,8-TCDD. These other sources were found in the sediments collected from Stations 17A (downstream of Green's bayou), 16 (mouth of Patrick Bayou), 26A (mouth of Vince Bayou), and 9 (middle San Jacinto River). These stations are located in the HSC (except station 9) and had maximum 2,3,7,8-TCDD concentrations of 42.1, 93.6, 75.5 and 27.8 ng/kg, respectively. These values are 1.5 to 3.4 times higher than the value reported to have been detected at Station 009 (27.8 ng/kg).

4.5.2 Houston Ship Channel Dioxin TMDL Project

The HSC TMDL study was undertaken by the University of Houston, in conjunction with Parsons and PBS&J (Rifai 2005). The initial work was completed between 2003 and 2005. This work was initiated because Section §303(d) of the Clean Water Act requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards and develop a list of such waters known as the §303(d) list. For each listed water body that does not meet a standard, states must develop a TMDL for each pollutant that has been identified as contributing to the impairment of water quality in that water body. TCEQ is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas. The ultimate goal of these TMDLs is to restore the quality of the impaired water bodies such that water quality standards are met (Rifai et al. 2005).

The overall purpose of the project was to develop a TMDL allocation of dioxin/furan sources in the HSC System, including upper Galveston Bay, and a plan for managing future discharges of these chemicals to correct existing water quality impairments. This included evaluating the occurrence and sources of dioxins and furans throughout the HSC including the associated rivers and bays.

The TMDL study evaluated the dioxin contributions to the HSC from point sources measured in the project and compared the result to the total contribution from sources for which a dioxin concentration was estimated in their modeling instead of measured.

Koenig (TCEQ) reviewed and presented data from the TMDL 2004 and 2005 sampling events, and showed the average sediment concentration rank ordered by concentration and by station (Figures 29 and 30, Koenig 2009). The diagram, showing rank order by average TEQ concentration, clearly shows the 1994 Station 009 (closest to the Impoundments) as being among the stations with the lowest average dioxin concentrations and at levels below the U.S. Department of Health and Human Services and EPA screening levels[4] (50 ppt and 39 ppt shown on TCEQ's slide, respectively, Figure 30).

During the high resolution sampling, a sample and a duplicate were collected from Station 15 from the buried Impoundment waste material (Rifai 2006a) (Figure 31). A sample and a duplicate were also collected at Station 11 off the Big Star property. The concentration of dioxins at Station 11 (550 ng/kg TEQ, average) likely resulted from dredging activities into the Impoundments and placement on the Big Star property as discussed above. The data from Rifai (2006a, Table 3.4) show that the Station 15 and 11 fingerprints are similar with significant peaks of 2,3,7,8-TCDD and 2,3,7,8-TCDF (Figure 32 and Table 7). Station 11 plots on the San Jacinto River Waste Pits (SJRWP) congener fingerprint graph like the Station 15 results. Additionally, Anchor QEA noted that the anomalous presence of elevated concentrations on this northeast portion of the Big Star property are coincident with historic sand separation operations.

The highest dioxin concentrations found in the Impoundment area resulted from sampling the source material itself and sediments that were dredged from the Impoundments and moved to the Big Star property. The TCRA cap has since been placed over these Impoundment materials (Anchor QEA 2013c,d). During the high-resolution sampling in the summer of 2005, the mill wastes in the Impoundments had reported concentrations of 32,752 ng/kg dry wt. TEQ (Station 15). The sediments at Station 11, adjacent to the sand separation area had a concentration of 550 ng/kg dry wt TEQ (Station 11). During the remedial investigation, the paper wastes deposited in the Impoundments were found to have a maximum of 15,400 ng-kg-dw TEQ (Integral and Anchor QEQ 2012a,b[5]). The high-resolution sampling events clearly show that

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[4] These screening levels are actually established for soil. The current EPA screening level for residential soil is 50 ppt TEQ and 664 ppt TEQ for industrial soil. Available at: (http://www.epa.gov/superfund/health/contaminants/dioxin/dioxinsoil.html).

[5] See Table 6-3 in Preliminary Site Characterization Report (Integral and Anchor QEA 2012a,b).

the dioxin and furan concentrations resulting from the paper mill wastes are not transported or have limited impact to the adjacent sediments (Figures 17 and 31). For example, Stations 7, 8, 9, and 17 near the Impoundment have significantly lower concentrations 14.03, 29.47, 11.61 and 30.69 ng/kg dry wt TEQ, respectively (Rifai 2006a[6], Table 3.4). These values can be compared to background concentrations of 5.3 to 54 ng/kg I-TEQ for rural and urban sediments, respectively[7] (U.S. EPA 2005).

Koenig went on to evaluate the other HSC "hot spots." He showed figures depicting sampling stations from the summer 2005 sampling event and noted the high dioxin concentrations near Patrick Bayou and downstream of Vince Bayou (segments 1006 and 1007) as described above. Koenig showed these segments as components of the modeling efforts. The original figure contained in Rifai (2008) shows the total concentrations for six homologues in sediments[8] (Figure 33).

The TMDL study documents many sources of dioxins in the HSC system that are contributing to numerous hot spots. Although the concentrations of dioxins and furans are elevated in the waste materials of the Impoundments, the high-resolution studies provide further evidence that these materials were of limited extent in the adjacent sediments. These sediments adjacent to the Impoundments have significantly lower dioxin and furan concentrations.

4.6 Fingerprinting and fate and transport studies have shown that Impoundment-related dioxins and furans have stayed within or in close proximity to the original boundaries of the Impoundments.

In a 2009 study by Texas A&M at Galveston commissioned by the TCEQ, the strong relationship between the organic, lignin rich waste materials from the Impoundments and dioxin/furans was observed (Louchouarn and Brinkmeyer 2009). One of the main objectives of their research was to evaluate the potential remobilization of contaminated particles from the Impoundments to the HSC and Galveston Bay. Louchouarn and Brinkmeyer (2009) found that:

> "Comparison of dioxin/furan signatures in the waste pit materials and sediments of the HSC suggested that the remobilization of contaminated particles does not occur beyond the close vicinity of the pit itself. The sediments of the HSC thus receive more diffuse inputs, entering the sedimentary environment through the air and water, which are comprised of a mixture of industrial and municipal sources."

The following section details observations from other studies that corroborate this finding for the areas in and upgradient of the Impoundments (Integral and Anchor QEA 2012a,b; Turner

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6 Rifai (2006) used the WHO_{98} TEQs for calculating TEFs

7 As reported in U.S. EPA (2005) on p. 12-15, 5.3 ng/kg I-TEQ was the concentration in the uppermost layer of sediments collected from 11 lakes "…relatively unimpacted by nearby industrial activity". U.S. EPA (2005) also reported a value of 54 ng/kg I-TEQ for urban sediments, citing Duarte-Davidson et al. (1997), a study in the U.K.

8 For example, TCDD, PeCDD, HxCDD, TCDF, PeCDF, and HxCDF; OCDD, and OCDF were not included.

and Broach 2011). These studies incorporate the use of fingerprinting to analyze samples both in and around the Impoundments and throughout the San Jacinto River, HSC, and Galveston Bay. The Turner and Broach (2011) analysis applies the fingerprinting analysis from the upper HSC to Galveston Bay, including areas not evaluated by Integral (Integral and Anchor QEA 2012a,b).

4.6.1 Fingerprinting

As described above, the TMDL and associated studies have shown and confirmed that there are numerous sources of dioxins in the HSC and vicinity (Rifai 2006b). U.S. EPA (2005) reported a national dioxin source inventory[9] and documented a range of activities and processes that result in the generation and release of dioxin and furan compounds into the environment. This included sources such as wastewater effluent, urban runoff, and aerial deposition.

As part of the RI/FS at the Impoundments, source identification of the waste material was undertaken (Integral and Anchor QEA 2012a,b). This included sampling from within the Impoundment perimeter and comparing those samples to samples collected from outside the Impoundments.

The source material from within the Impoundments is characterized by high proportions of 2,3,7,8-TCDD and 2,3,7,8-TCDF.

Integral performed an unmixing analysis using data for the seventeen 2,3,7,8-substituted dioxin and furan congeners in all sediment samples collected within and around the Impoundments since 2009, and for all of the soil samples in the Texas Department of Transportation right-of-way adjacent to the Impoundments, and north of I-10. Integral used these multiple source types, and the sufficient number of samples to mathematically estimate the mixing processes (Integral and Anchor QEA 2012a,b). To accomplish this, dioxin and furan patterns (fingerprints) were calculated for each sample by dividing the concentration of each individual congener by the sum of concentrations of all 17 congeners (U.S. EPA 2003).

The results of this analysis found that there were two source types in the area north of I-10 (Figure 34):

- Type 1: An urban background source characterized by high octachlorodibenzo-*p*-dioxin (OCDD)
- Type 2: Material from the Impoundments characterized by 2,3,7,8-TCDD and 2,3,7,8-TCDF.

The two source types that have, in various proportions, contributed to the dioxin and furan mixtures in soil and sediment samples near the Impoundments. The source patterns showed a generalized urban background source type ("End Member 1" or EM1) characterized by the large proportion of OCDD (greater than 85 percent of the total dioxin and furan concentration); and a

9 A draft update to this inventory was issued August 7, 2013.

specific source type (EM2) with a dioxin and furan congener pattern that is very similar to samples taken directly from the wastes in the Impoundments. This source type is characterized by the dominance of tetrachlorodibenzo-*p*-dioxin (TCDD) (about 20 percent of the total) and tetrachlorodibenzofuran (TCDF; about 65 percent of the total). The pattern in EM1 is similar to generalized urban background sources documented by U.S. EPA (2003a) and is also similar to sludge samples from facilities upstream of the Impoundments, and to effluents from an outfall near the Impoundments (citation).

The Integral analyses suggest that the spatial extent of sediments affected by paper mill waste from the Impoundments may be limited to within the area immediately around the Impoundments, small areas in the surrounding sediments, and very few soil samples (Integral and Anchor QEA 2012a,b). Surface and subsurface sediment samples in only a few locations in the area outside the Impoundment perimeter were identified to have some quantifiable contribution of materials with the dioxin and furan pattern characteristic of paper mill wastes. These were likely a result of the dredging activities discussed above. The majority of samples of soil and sediment from the area around the Impoundments had a composition of dioxins and furans characterized by a single source type, EM1, which is representative of urban background and sludge from upstream facilities or effluents from an outfall near the Impoundments.

Turner and Broach (2011) found similar results for the sediments from the Impoundments and the sediments from upstream of the Impoundments (Figures 35 and 36). Turner and Broach (2001) displayed the upstream results with and without OCDD, because OCDD is the dominant congener (Figure 36). Their observations of the upstream samples showed they were dominated by OCDD; 1,2,3,4,6,7,8 HpCDD; octachlorodibenzofuran (OCDF), 1,2,34,6,7,8 HpCDF; and 1,2,3,4,7,8,9 HpCDF.

Turner and Broach (20011) also provided an analysis of sediment samples collected near the Impoundments and concluded that the fingerprint is similar to the waste material but with considerably more HpCDD and OCDFs and less PeCDFs and HxCDFs (Figure 37). They noted that the percent decline in TCDD and TCDF occurs as the percentage of HpCDD increases (Turner and Broach 2011). These results are comparable to those of Integral from the unmixing analysis (Integral and Anchor QEA 2012a,b). The fingerprinting by Integral only provided fingerprinting for samples located within the remedial investigation boundary and did not carry the analysis downstream.

Turner and Broach (2011) did carry their analysis through the upper HSC into Galveston Bay.

Their observations of the HSC Buffalo Bayou area included the following (note that OCDD was not included in the analyses as it is typically the most dominant congener):

- Patrick Bayou to Tucker Bayou dominated by OCDF (Figure 38)
    - Some HpCDDs, TCDFs, and HCDFs
- Greens Bayou to Patrick Bayou dominated by OCDF (Figure 39)
    - Some HpCDDs, more TCDFs, and HCDFs

- Sims Bayou to Greens Bayou dominated by OCDF (Figure 40)
  - Some HpCDDs, TCDFs, and HCDFs
  - Small amounts of numerous other congeners.

Their observations for the HSC side bays (Burnett, Scott, and San Jacinto Bays) (Figure 41) were that each of the three side bays had similar fingerprints (excluding OCDD) dominated by OCDF and followed by HpCDDs, TCDFs, HpCDFs, and TCDDs.

Their observations for Galveston Bay (excluding OCDD) included (Figure 42):

- Fingerprint for all stations dominated by HpCDDs, followed by OCDF, HpCDDs, and HpCDFs
- Decreasing TEQ with distance downstream
- The sediments of Galveston Bay have similar fingerprints to the samples collected above (i.e., upstream of) the Impoundments

4.6.2 Fate and Transport of Dioxins and Furans from the Impoundments

Fingerprinting is only one technique used to evaluate the sources of dioxins and furans in this system. It is a proven tool and very useful. But, clearly the transport and fate of dioxins in the HSC, San Jacinto River, and Galveston Bay is far more complex. Multiple sources have contributed to the total load of dioxins and furans in the system. Some may have been transported farther than others. But the fingerprints in the upstream San Jacinto River and the downstream Galveston Bay are very similar and appear to be background (Turner and Broach 2011). In fact, the TEQ concentration range is similar and consistent with general urban background (Integral and Anchor QEA 2013c,d, Figures 6-14 and 6-12).

As part of the remedial investigation of the Site, the highest concentrations of dioxins and furans were found within the original perimeter of the Impoundments. Several cores in the eastern Impoundment show very low dioxin and furan concentrations (Figure 43) (Integral and Anchor QEA 2012a,b). Coring in the western Impoundment showed that there were high concentration waste materials above low concentration, underlying silts and clays. Furthermore, they are both now covered by a TCRA cap (Anchor QEA 2010; Integral and Anchor QEA 2013c,d)). Sediment dioxin and furan concentrations from the eastern side of the east Impoundment to outside the Impoundment perimeter decrease rapidly with distance, except for the sand separation area that was impacted by dredging activities. These data demonstrate that the relative mobility of dioxins and furans in the waste materials is low.

The following section discusses the hydrodynamic modeling that was performed to address net depositional areas versus those that might be eroding in the area of the Impoundments to assist in the evaluation of potential transport mechanisms.

4.6.3 Hydrodynamic Model

During the remedial investigation, a hydrodynamic, sediment transport, and chemical fate and transport model was developed. The hydrodynamic model encompasses the San Jacinto River from the Lake Houston Dam to the confluence with the HSC, which also includes a portion of the area south of the Impoundments. The resolution of the model grid cells is spatially variable, with high resolution in the region near the Impoundments. The sediment transport and chemical fate models used the same numerical grid as the hydrodynamic model.

The chemical fate and transport model used the predictions from the hydrodynamic and sediment transport models. It was developed for three dioxin/furan congeners (2,3,7,8-TCDD, 2,3,7,8-TCDF, and OCDD) and simulated the key processes affecting a hydrophobic organic contaminant within a surface water/sediment system, including (Anchor QEA 2012a):

- Transport within the water column
- Interactions with particles through partitioning
- Exchanges between the sediment bed and surface water through deposition, erosion, and surface porewater exchange
- Vertical mass transport within the sediment bed.

Of key importance is that the model predicts net sedimentation rates within the area of the Impoundments with reasonable accuracy. The model showed that net deposition within this area was reasonably consistent with the radioisotope analysis. This is important because it says that particles that could contain dioxins and furans are not leaving the area, and that particles from upstream are being deposited in the area of the Impoundments. This modeling was confirmed by evaluating the vertical distribution of radioisotopes in subsurface sediment cores (Integral and Anchor QEA 2013c,d). The purpose of the profiling was to determine net sedimentation rates, based on measurement and analysis of lead-210 (^{210}Pb) and cesium-137 (^{137}Cs) in 10 sediment cores collected from the San Jacinto River. The radioisotope studies showed net sedimentation rates in the areas of the Impoundments to be 0.4 to 3 cm/year. Thus, modeling and measurements confirm that net deposition is taking place in the area around the Impoundments.

Figures

USEPA's Preliminary Site Perimeter
Original 1966 Perimeter of the Impoundments North of I-10
Approximate TCRA Footprint
Soil Investigation Area 4

ANCHOR QEA
integral consulting inc.

0 800
Scale in Feet

[a] Designation of the sand separation area is intended to be a general reference to areas in which such activities are believed to have taken place based on visual observations of aerial photography from 1998 through 2002.

FEATURE SOURCES:
Aerial Imagery: 0.5-meter. Photo Date: 01/14/2009
Texas Strategic Mapping Program (StratMap), TNRIS

Figure 1-1
Overview of Area within USEPA's Preliminary Site Perimeter
Remedial Investigation Report
San Jacinto River Waste Pits Superfund Site

P:\Projects\C643_SJWaste_IPC\Production_MXDs\RI_Report\Figure_1-1_AreaOverview.mxd 11/28/2012 1:32:36 PM

Figure 1. Overview of area within EPA's preliminary site perimeter with 1966 photograph inserted

1304001.000 0101 08/01/13 WA

C:\Users\dholmer\appdata\local\temp\AcPublish_9968\09055701-RP-093.dwg Fig 1-2

Dec 03, 2012 11:49am dholmer

SOURCE: Google Map Pro 2009

NOTE: TCRA = Time Critical Removal Action

LEGEND:

— — — Original 1966 Perimeter of the Impoundments North of I-10

Approximate TRCA Footprint

0 500

Scale in Feet

ANCHOR QEA

integral consulting inc.

Figure 1-2
TCRA Vicinity Map
Remedial Investigation Report
San Jacinto River Waste Pits Superfund Site

Figure 2. Impoundment vicinity map with 1966 photograph inserted (Figure 1-2 from Anchor QEA 2011a)

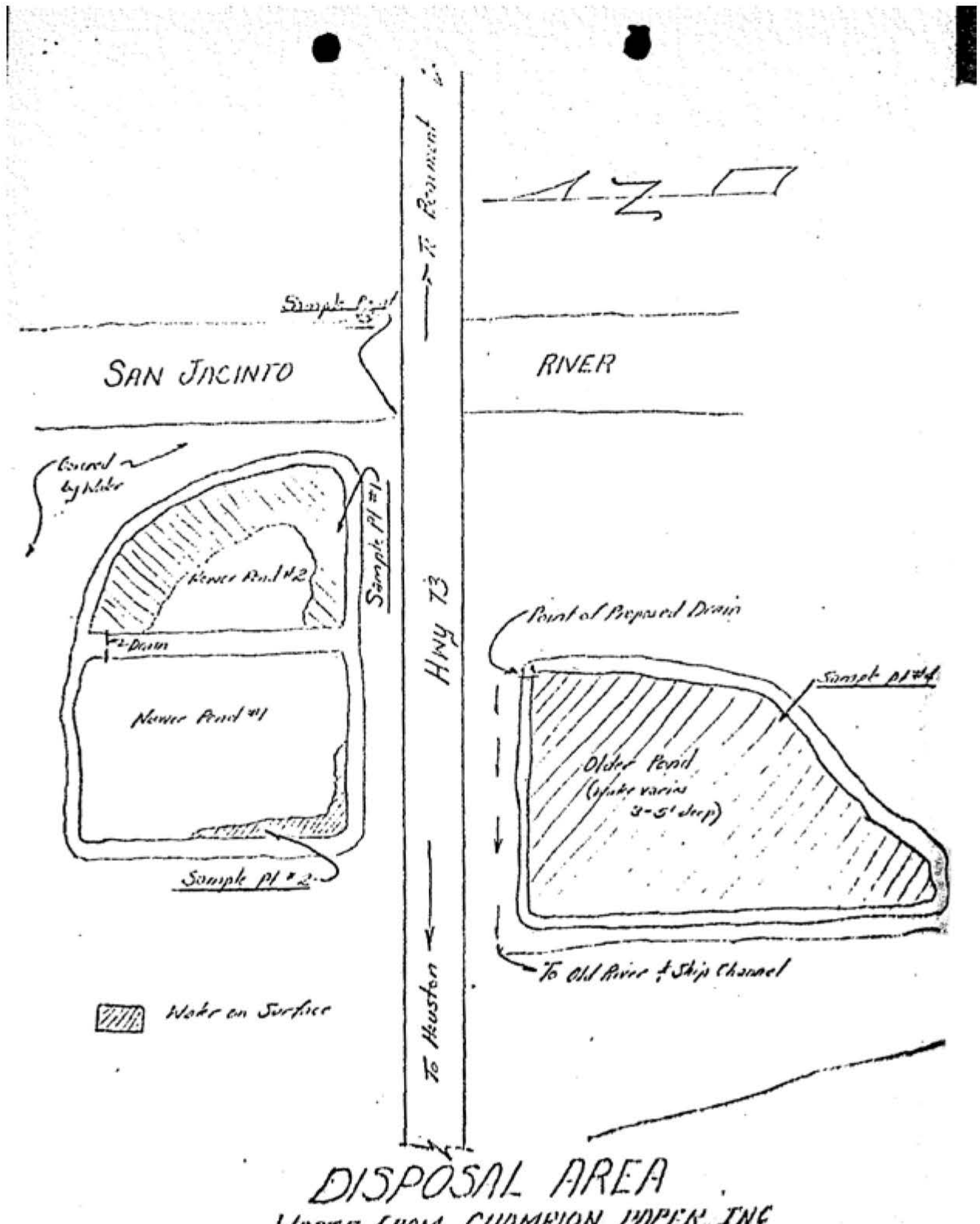
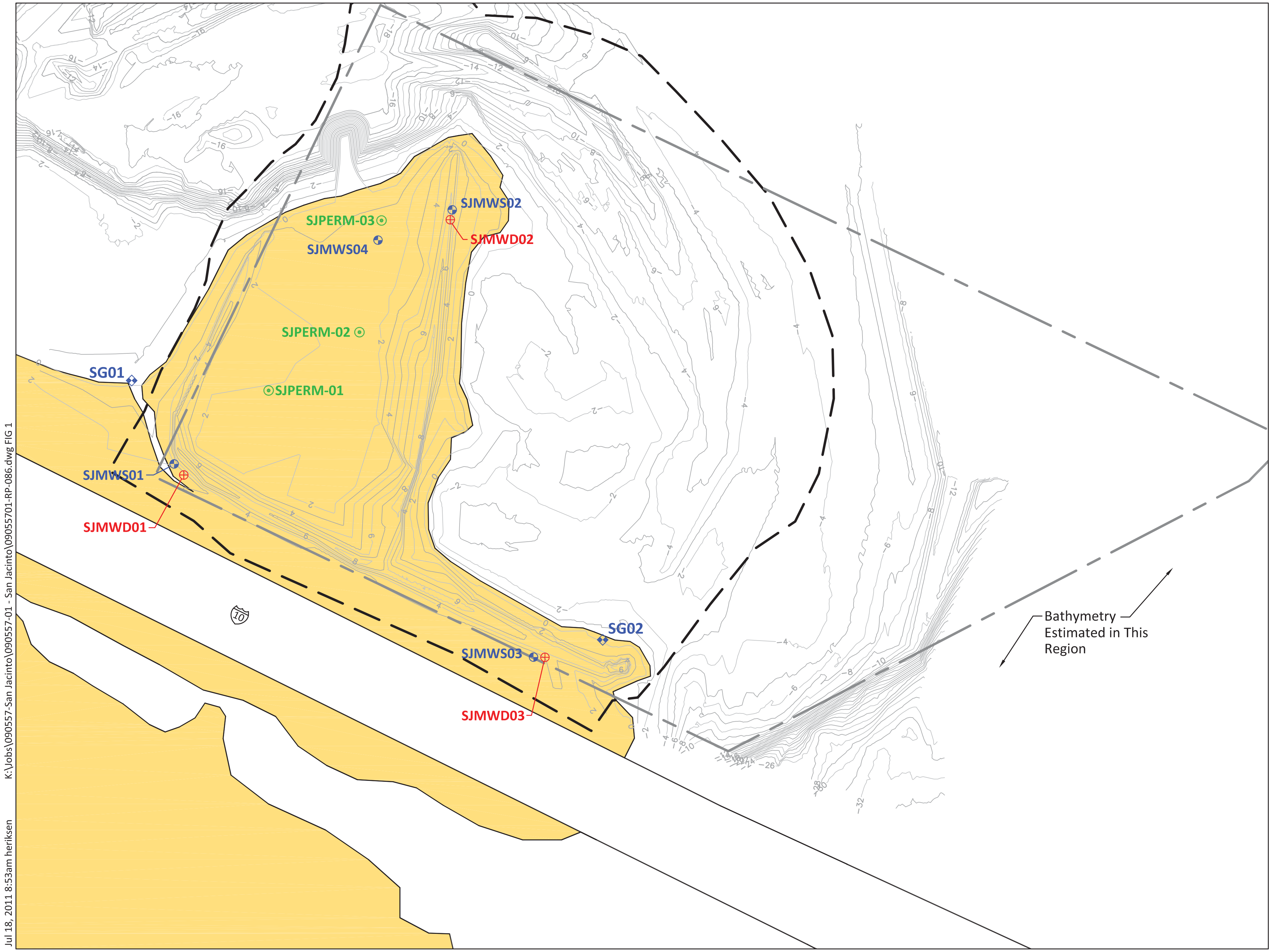


Figure 3. Site map (from Thonpson 1966)



Number	Easting	Northing
SJMWS01	3216654.64	13857356.47
SJMWD01	3216668.35	13857340.83
SJMWS02	3217048.21	13857716.27
SJMWD02	3217045.49	13857702.27
SJMWS03	3217163.24	13857082.92
SJMWD03	3217179.41	13857082.67
SJMWS04	3216943.21	13857673.38
SJPERM-01	3216788.39	13857460.49
SJPERM-02	3216916.93	13857543.05
SJPERM-03	3216948.14	13857701.19
SG01	3216594.63	13857474.61
SG02	3217261.16	13857107.46

LEGEND:

- Approximate 1966 Berm Alignment Perimeter
- Virgil C. McGinnes Trustee Property Line
- Approximate Limit of Vegetated Area (Shoreline)
- SG02 — Staff Gauge
- SJMWS03 — Shallow Monitoring Well
- SJMWD03 — Deep Monitoring Well
- SJPERM-02 — Permeability Core

0 150
Scale in Feet

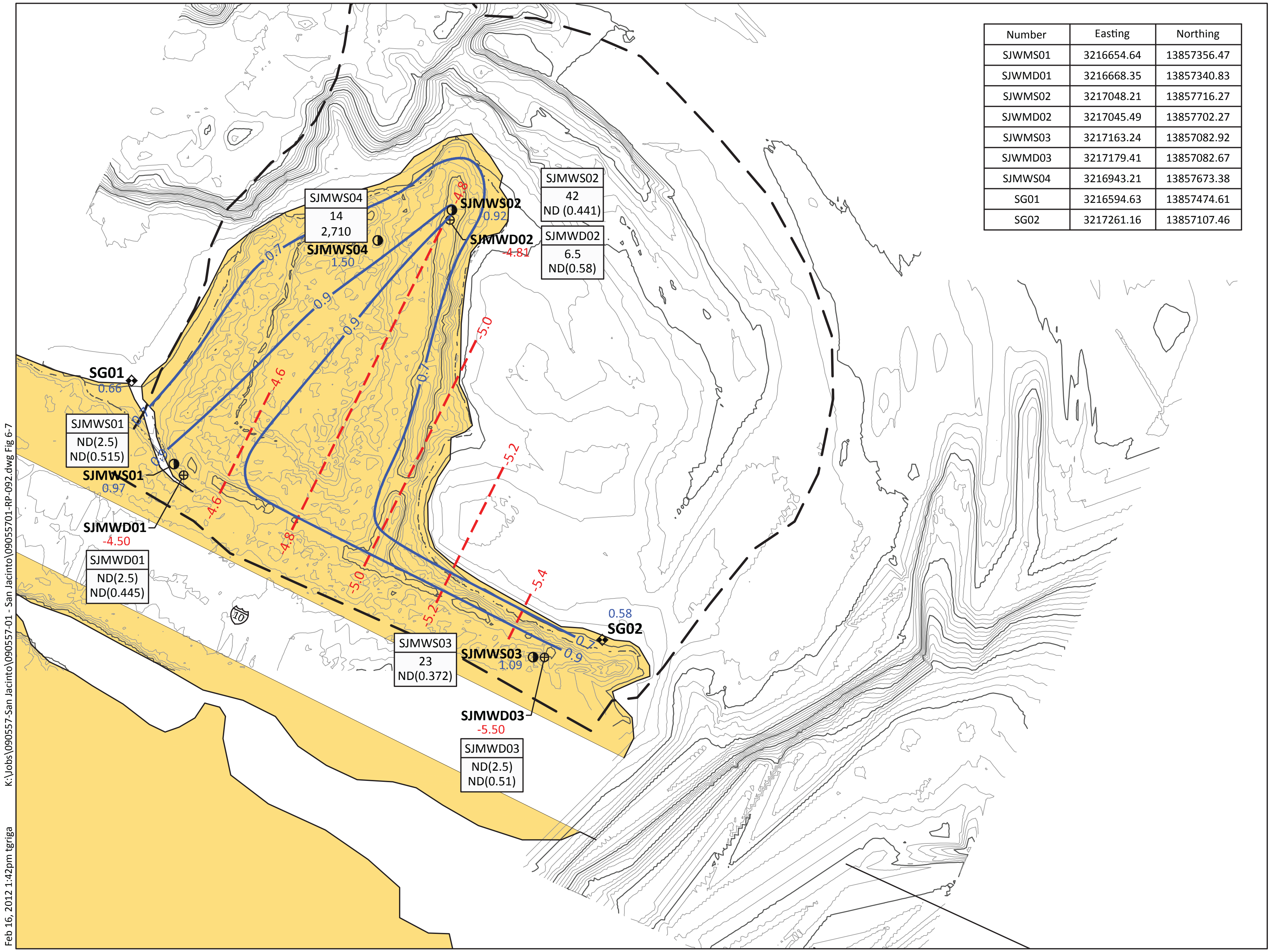
SOURCE: Drawing prepared from electronic file provided by US Army Corps of Engineers.
HORIZONTAL DATUM: Texas South Central NAD 83, US Survey Feet.
VERTICAL DATUM: NAVD 88.
NOTE: Water level in SJMW04 likely perched. Water level elevation not included in shallow potentiometric surface contours as it is screened in a disparate unit (i.e. clayey waste) relative to other shallow wells (screened in coarse alluvium).

DRAFT

Figure 1
Sampling and Monitoring Locations
Field Sampling Report - Groundwater Study
SJRWP Superfund Site/MI

Figure 4. Sampling and monitoring locations field sampling report – groundwater study (from Anchor QEA and Integral 2011a)

Number	Easting	Northing
SJMWS01	3216654.64	13857356.47
SJMWD01	3216668.35	13857340.83
SJMWS02	3217048.21	13857716.27
SJMWD02	3217045.49	13857702.27
SJMWS03	3217163.24	13857082.92
SJMWD03	3217179.41	13857082.67
SJMWS04	3216943.21	13857673.38
SG01	3216594.63	13857474.61
SG02	3217261.16	13857107.46



LEGEND:

Original 1966 Berm Impoundment Perimeter	
Approximate Limit of Pre-TCRA Vegetated Area (Shoreline)	
SG02	Staff Gauge
SJMWS03	Shallow Monitoring Well
SJMWD03	Deep Monitoring Well
1.09	Alluvial Potentiometric Elevation (ft)
0.9	Alluvial Potentiometric Surface (ft)
-5.50	Chicot Aquifer Potentiometric Elevation (ft)
-5.4	Chicot Aquifer Potentiometric Surface (ft)
SJMWS03 / 23 / ND(0.372)	Well ID; TSS Concentration in Groundwater (mg/L); 2,3,7,8-TCDD Concentration in Groundwater (pg/L)
ND(0.372)	Not Detected (One Half of the Detection Limit)

0 150
Scale in Feet

SOURCE: Drawing prepared from USACE. Bathymetry has been compiled from a 2/16/09 and 6/12/10 survey conducted by Hydrographic Consultants, LTD of Bellaire, Texas. Upland contours generated from LiDAR data collected by Merrick & Co., published 11/4/2008.
HORIZONTAL DATUM: Texas South Central NAD 83, US Survey Feet.
VERTICAL DATUM: NAVD 88.

NOTES:

1. Water level in SJMWS04 likely perched. Water level elevation not included in shallow potentiometric surface contours as it is screened in a disparate unit (i.e., gray sandy clay) relative to other shallow wells (screened in coarse alluvium).

Feb 16, 2012 1:42pm tgriga K:\Jobs\090557-San Jacinto\090557-01 - San Jacinto\09055701-RP-092.dwg Fig 6-7

Figure 6-7
Alluvial and Chicot Aquifer Potentiometric Surface Map - January 10, 2011
SJRWP Preliminary Site Characterization Report
SJRWP Superfund Site/MIMC and IPC

ANCHOR QEA
integral consulting inc

Figure 5. Alluvial and Chicot Aquifer potentiometric surface map

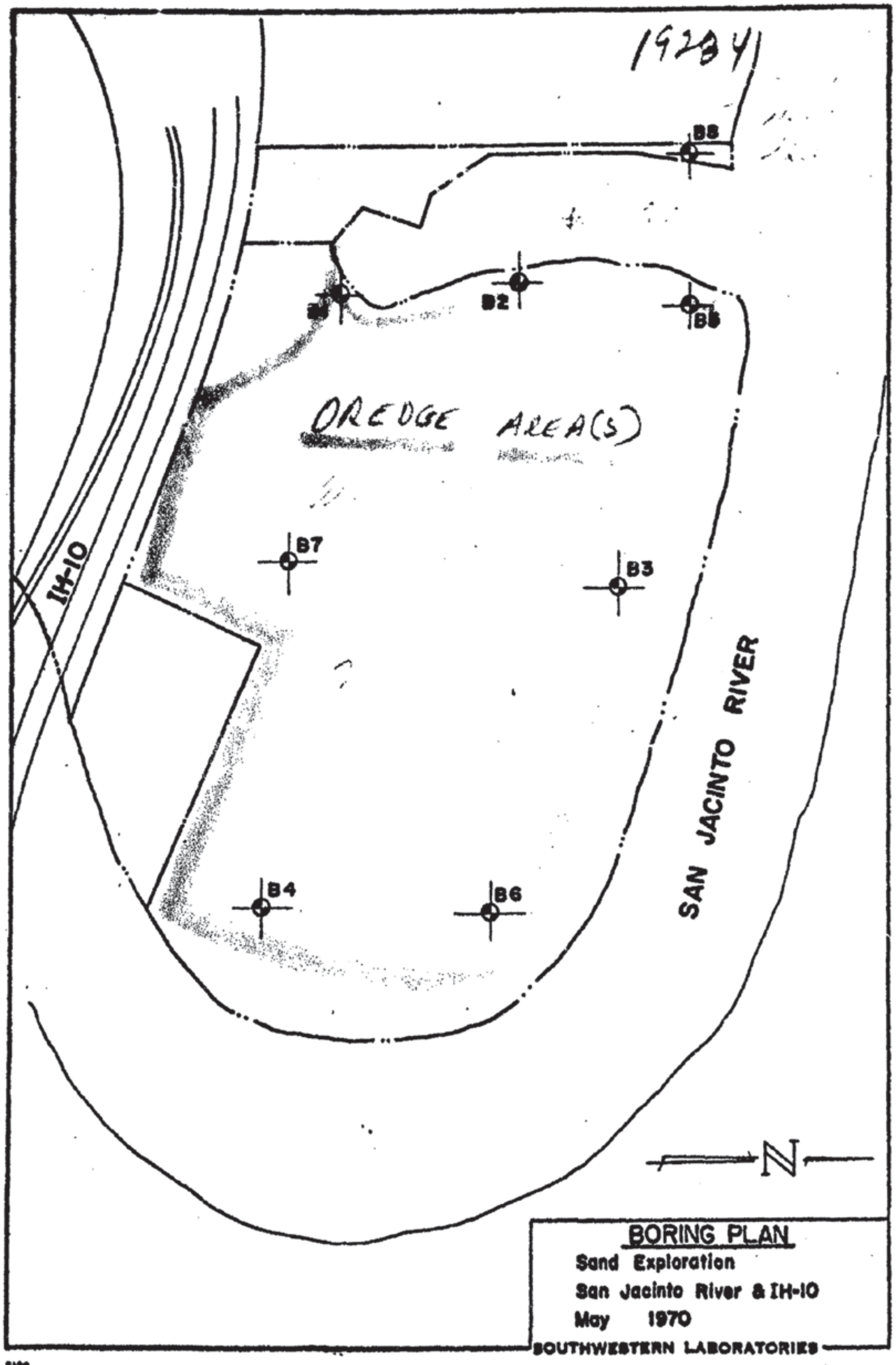
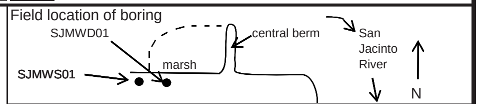


Figure 6. Boring plan from 1970 subsurface exploration plan
(HIT 1970–2004; HIT2009)

ANCHOR QEA — LOG OF EXPLORATORY BORING

CLIENT/PROJECT NAME: MIMC/IPC San Jacinto River Waste Pits
BORING #: SJMWD01
PROJECT NUMBER: 090557-01.01
DATE BEGAN: 1/7/2011
GEOLOGIST/ENGINEER: Chris Torell
DATE COMPLETED: 1/8/2011
DRILLING CONTRACTOR: Miller Drilling
TOTAL DEPTH: 65'
DRILLING METHOD: sonic, sonic core barrel
SHEET 1 OF 4
HOLE DIAMETER: 10", 6"

Field location of boring



WELL OR PIEZOMETER DETAILS	SAMPLE NUMBER	RECOVERY (feet)	DEPTH SAMPLED	DEPTH IN FEET	SOIL GROUP SYMBOL (USCS)	LITHOLOGIC DESCRIPTION
	55	0.5 5			SP	FINE SAND - tan, wet, little silt
	56	0.5		1	MH	SILT and CLAY - grey, roots
						ALLUVIUM
	40		see list below	2		
	41			3		
				4		
				5		
		3.5			MH	as above
				6		
				7		
				8		
			SJMWD01S0910		SP	FINE SAND - grey, wet, trace silt
				9		
	42			10		
		4.5			SP	as above
				11		
				12		
				13		
			SJMWD01S1415	14		
	43			15		
		4.5			SM	as above
				16		
				17		
					CL	CLAY and SILT - some very fine sand and shells
				18		
					SP	FINE SAND - grey, wet, trace silt
			SJMWD01S1920	19		
	44			20		

Remarks: 7" steel outer casing 0-39; inner bentonite slurry grout 0-48; outer bentonite slurry grout 0-38; inner 2" ID PVC riser +2 -55

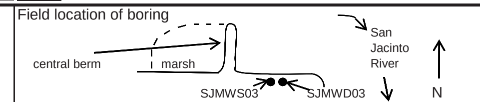
40 SJMWD0150005 41 SJMWD01D2 55 SJMWS01-0-6 56 SJMWS01-6-12

ANCHOR023623

ANCHOR QEA — LOG OF EXPLORATORY BORING

CLIENT/PROJECT NAME: MIMC/IPC San Jacinto River Waste Pits
BORING #: SJMWD03
PROJECT NUMBER: 090557-01.01
DATE BEGAN: 1/5/2011
GEOLOGIST/ENGINEER: Chris Torell
DATE COMPLETED: 1/6/2011
DRILLING CONTRACTOR: Miller Drilling
TOTAL DEPTH: 61'
DRILLING METHOD: sonic, sonic core barrel
SHEET 1 OF 4
HOLE DIAMETER: 10", 6"

Field location of boring



WELL OR PIEZOMETER DETAILS	SAMPLE NUMBER	RECOVERY (feet)	DEPTH SAMPLED	DEPTH IN FEET	SOIL GROUP SYMBOL (USCS)	LITHOLOGIC DESCRIPTION
	37 24	0.5 4			ML	SILT and FINE SAND - dark brown, wet, little clay and shells
	38	0.5		1		ALLUVIUM
				2		
				3		
			see list below	4		
				5		
		3.6			CL	CLAY - dark grey, some silt and trace very fine sand, peaty at 5.75' and 6.8'
				6		
				7		
				8		
			SJMWD03S0910	9		
	25			10		
		3			CL	as above
				11		
				12		
					SM	FINE SAND - dark grey, wet, some silt and clay
				13		
			SJMWD03S1415	14		
	26			15		
		3.25			SM	as above, rootlets @ 16'
				16		
				17		- grey/dark brown, some thin clay lenses
				18		
			SJMWD03S1920	19		
	27			20		

Remarks: 6" steel outer casing 0-39; inner bentonite slurry grout 0-45; outer bentonite slurry grout 0-38; 2" ID PVC riser +2 - 51

37 SJMWS03-0-6 24 SJMWS03-6-12 38 SJMWD03S0005

ANCHOR023631

Figure 7. Boring logs from borings SJMWD01 and SJMWD03 (Anchor QEA and Integral 2011a,b)

1304001.000 0101 08/01/13 WA

IP0370765

Figure 8. Map showing the beach areas where sediment particle size distributions were measured (from Integral and Anchor QEA 2013a,b)

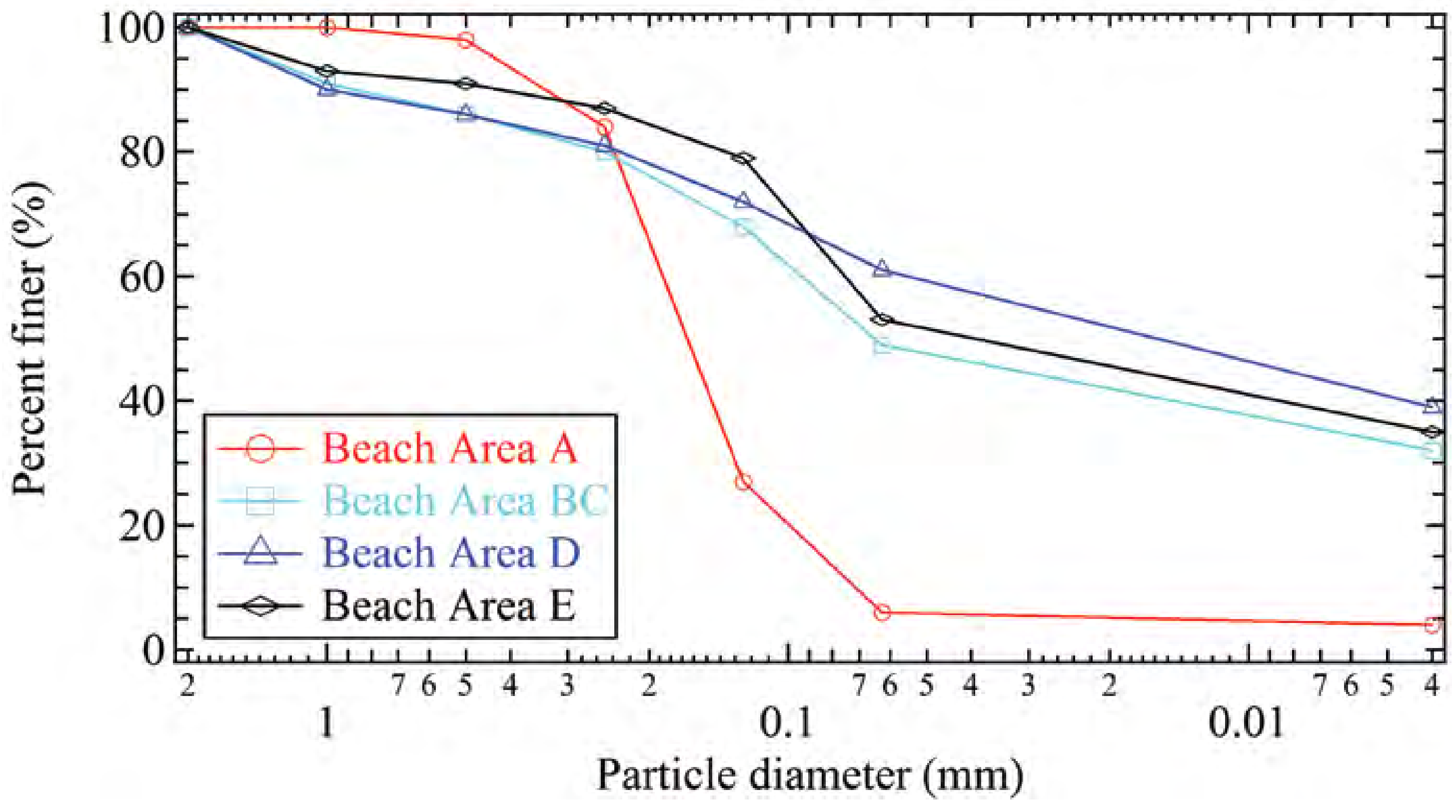


Figure 9. Particle size distribution for beach area sediment samples (as estimated from Figure 5-10 in Integral and Anchor QEA 2013a,b)

1304001.000 0101 08/02/13 WA

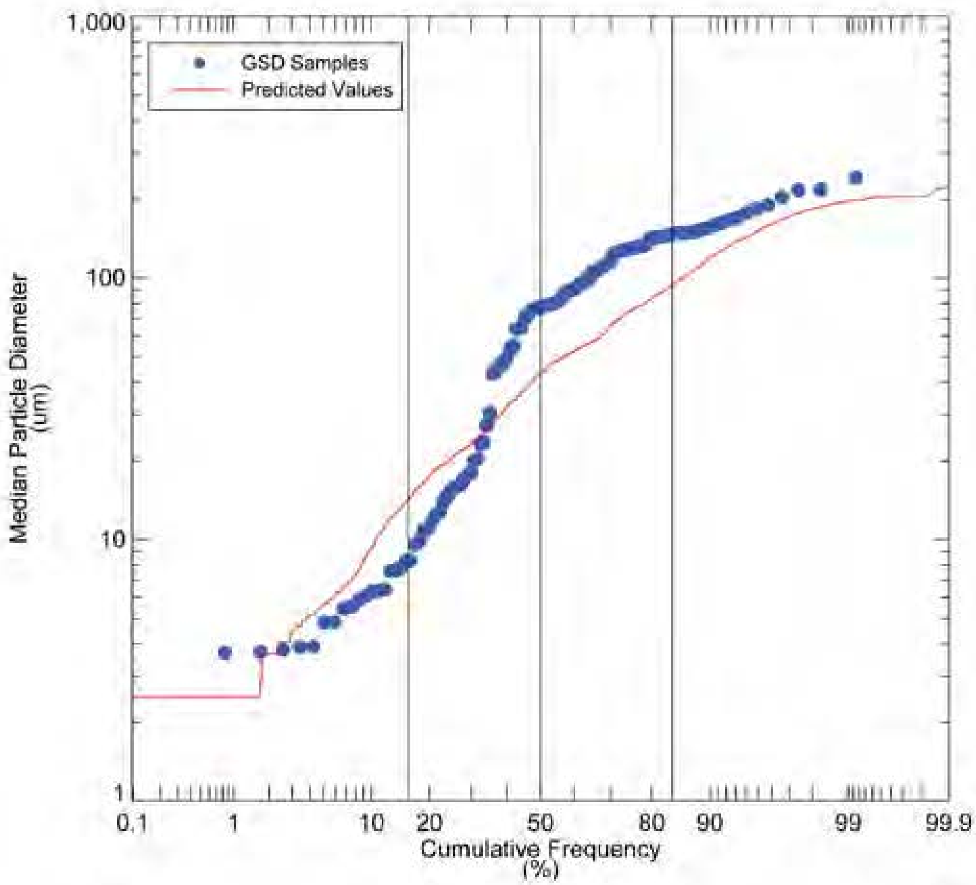


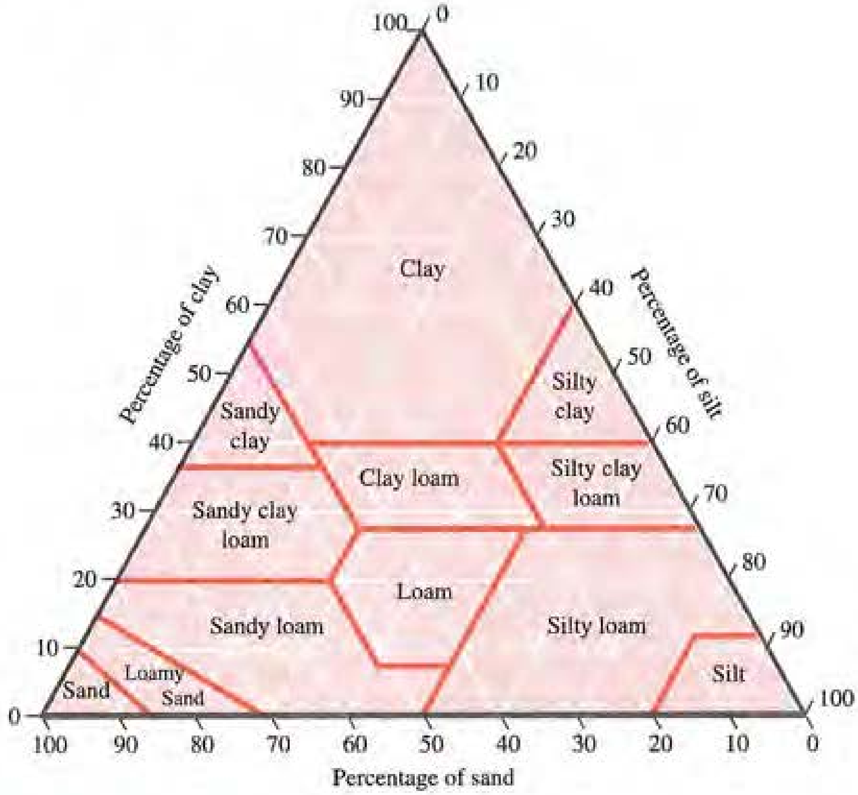
Figure 4-6

Cumulative Frequency Distribution of Median Particle Diameter (D_{50}) for GSD Samples and Predicted Values
Chemical Fate and Transport Modeling Study
San Jacinto River Waste Pits Superfund Site

ANCHOR QEA

ANCHOR0006815

Figure 10. Median particle sizes from 169 samples (Anchor QEA 2012a, Fig. 4-6)



▼ **FIGURE 3.1** U.S. Department of Agriculture textural classification

chart is based on only the fraction of soil that passes through the No. 10 sieve. Hence, if the particle-size distribution of a soil is such that a certain percentage of the soil particles are larger than 2 mm in diameter, then a correction will be necessary. For example, if soil B has a particle-size distribution of 20% gravel, 10% sand, 30% silt, and 40% clay, the modified textural compositions are

$$\textit{Sand-size}: \frac{10 \times 100}{100 - 20} = 12.5\%$$

$$\textit{Silt-size}: \frac{30 \times 100}{100 - 20} = 37.5\%$$

$$\textit{Clay-size}: \frac{40 \times 100}{100 - 20} = 50.0\%$$

Based on the preceding modified percentages, the USDA textural classification is clay. However, due to the large percentage of gravel, it may be called gravelly clay.

Figure 11. U.S Department of Agriculture textural classification (Das 1994, Fig. 3-1)

0 800
Feet

Figure 6
2002 Aerial Photo
Impact of Dredging on the San Jacinto Waste Pits TCRA Site
SJRWP Superfund/MIMC and IPC

Figure 12. 2002 aerial photo impact of dredging on the Impoundments (from Anchor 2011a, Figure 6)

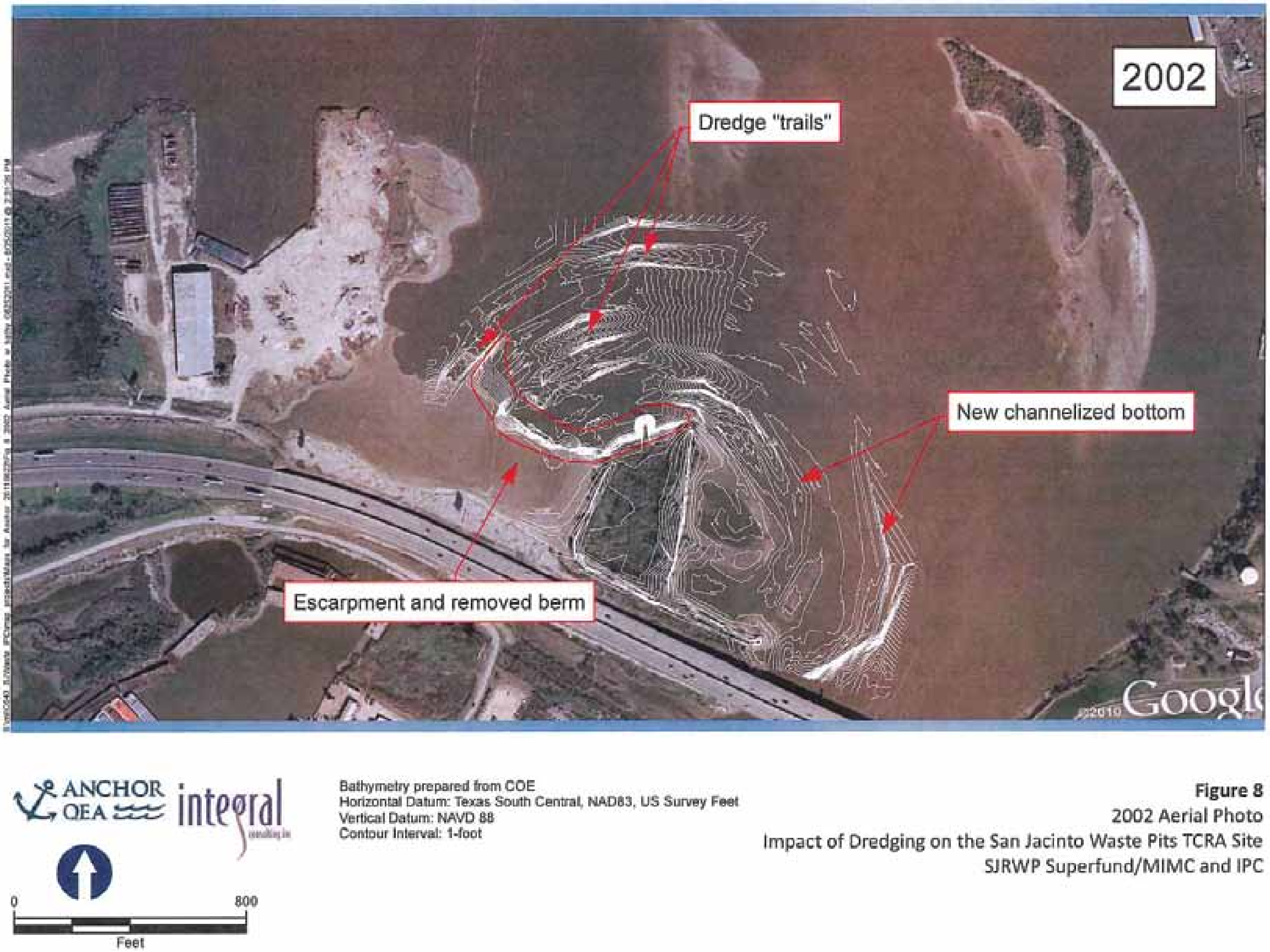


Figure 13. 2002 aerial photo, impact of dredging on the Impoundments with bathymetry (from Anchor 2011a, Figure 8)

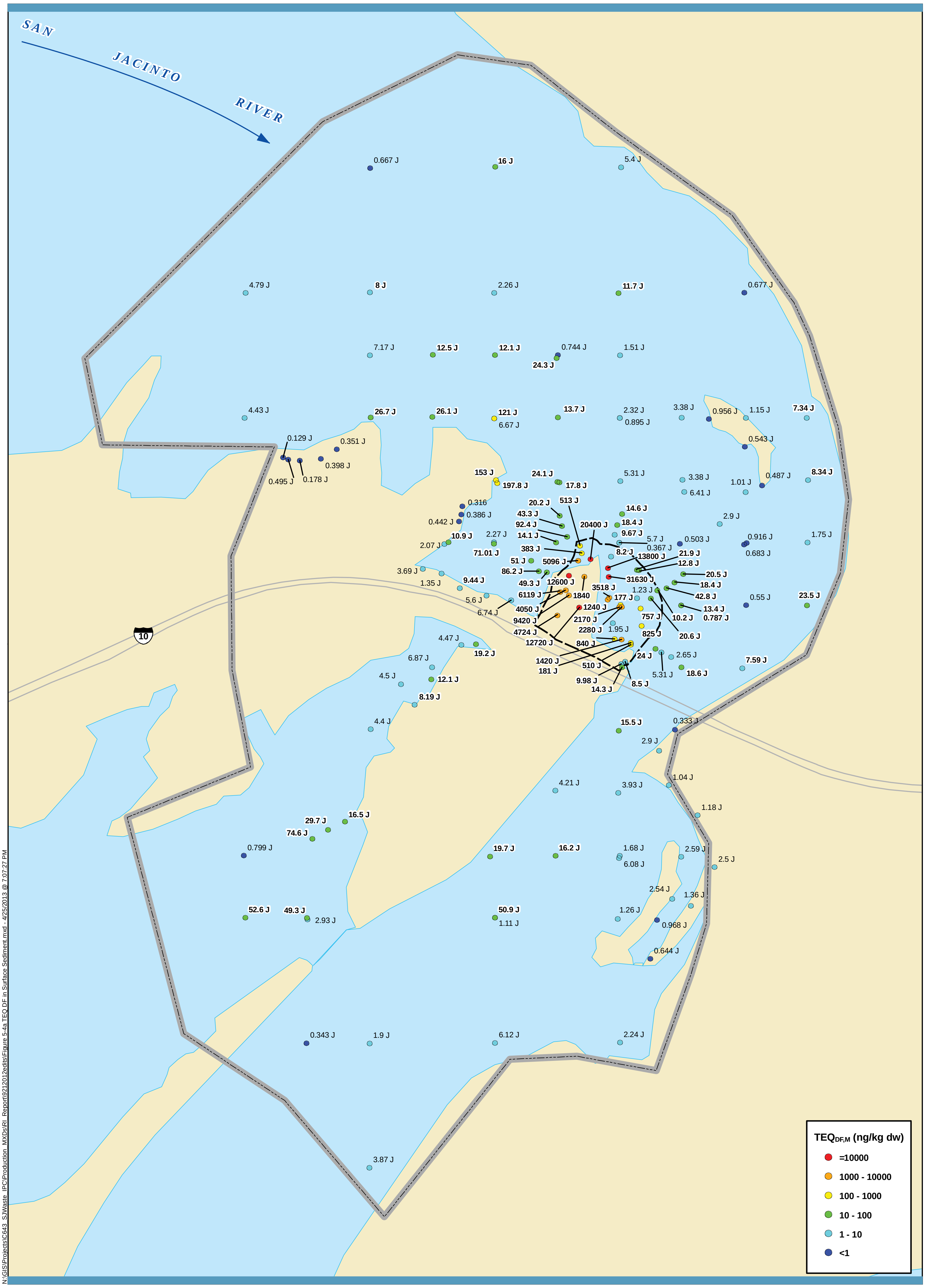
Figure 14. 1966 and 2002 aerial photo, impact of dredging on the Impoundments with 2009 bathymetry (from Anchor 2011a, Figure 9)

Figure 15. Sand mining in the Impoundments area (from Koenig 2009, p. 15)

Figure 7
2009 Aerial Photo
Impact of Dredging on the San Jacinto Waste Pits TCRA Site
SJRWP Superfund/MIMC and IPC

0 800
Feet

Figure 16. 2009 aerial photo of impact of dredging on the Impoundments showing new flow channel and berm degradation due to dredging (from Anchor QEA 2011a, Figure 7)



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USEPA's Preliminary Site Perimeter

Original 1966 Perimeter of the Impoundments North of I-10

Surface Sediment Sample Location

0 800
Feet

Notes:
TEQ$_{DF,M}$ = Toxicity equivalent for 2,3,7,8-TCDD calculated for dioxins and furans using mammalian TEFs from van den Berg et al. (2006) (nondetect = 1/2 detection limit)

J = Estimated. One or more congeners used to calculate the TEQ$_{DF,M}$ was not detected.

Concentrations in bold indicate values above reference envelope value (REV); REV = 7.2 ng/kg dw

Figure 5-4a
TEQ$_{DF,M}$ Concentrations in Surface Sediment
Remedial Investigation Report
San Jacinto River Waste Pits Superfund Site

Figure 17. TEQ$_{DF}$ concentrations in surface sediment (from Integral and Anchor QEA 2013c,d, Figure 5-4a)

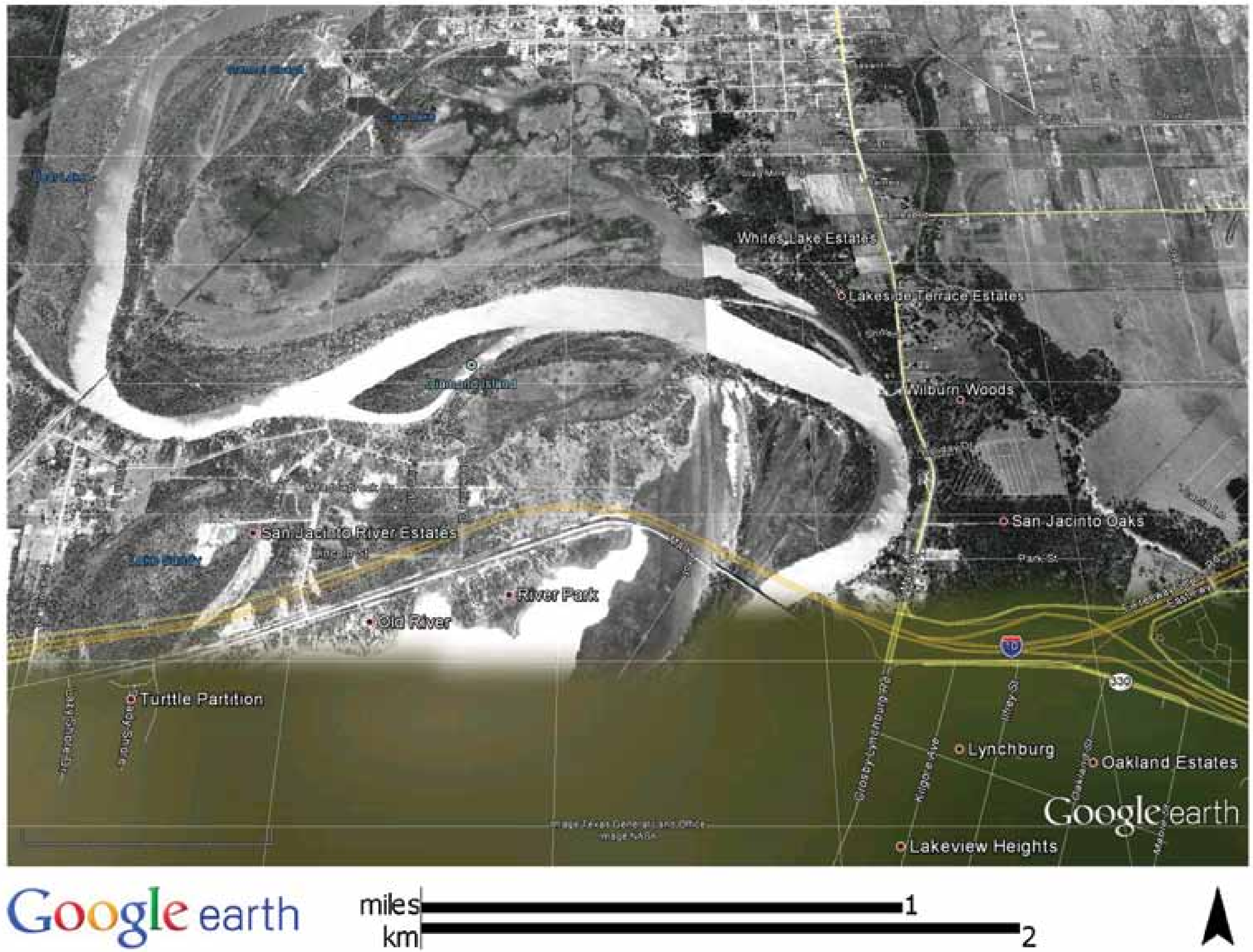


Figure 18. San Jacinto River near the I-10 overcrossing in December 1944

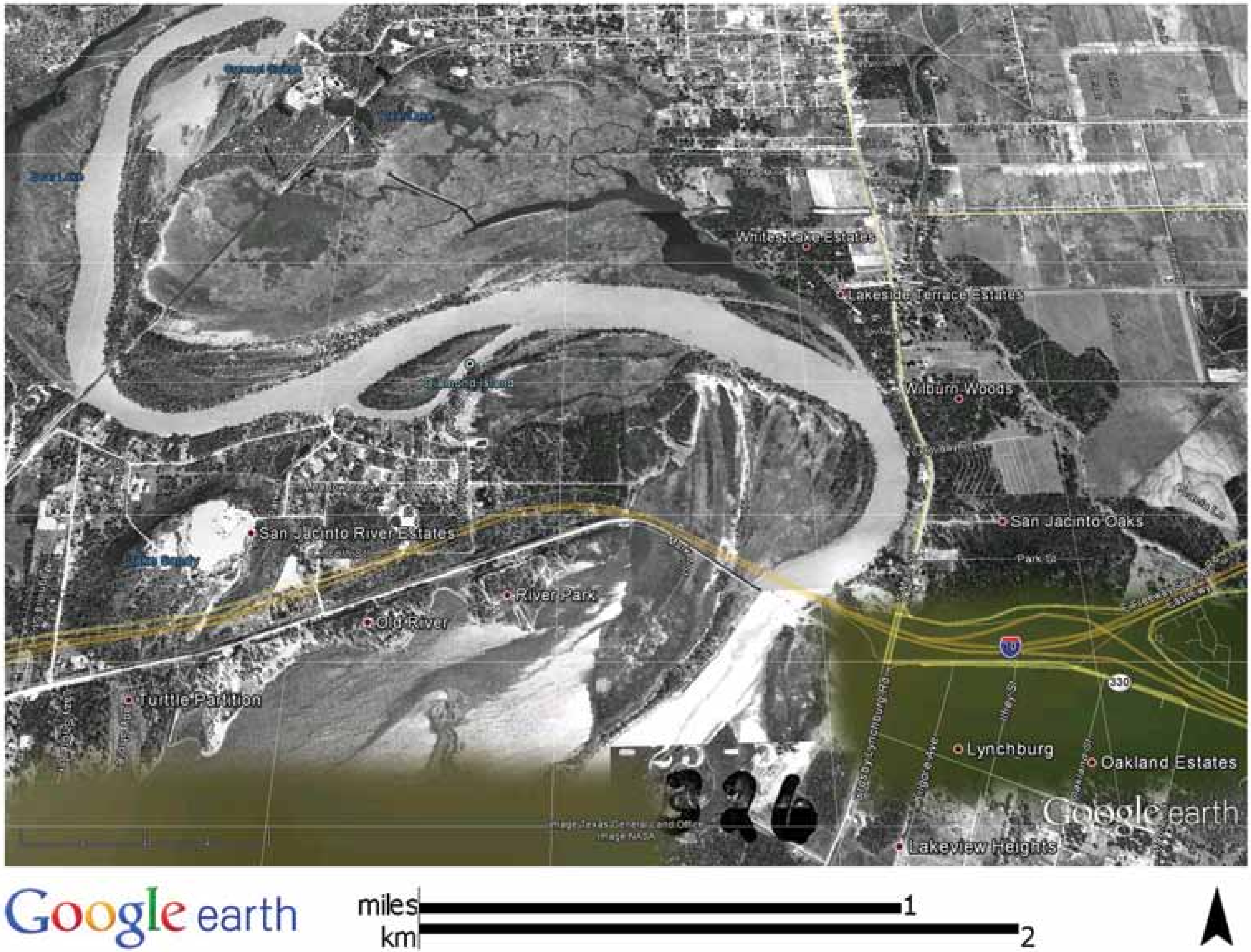


Figure 19. San Jacinto River near the I-10 overcrossing in December 1953

Construction of the Lake Houston Dam, 1953-1954.
Courtesy of HoustonWaterWorks Museum + Education Center.

Figure 20. Construction of the Lake Houston Dam

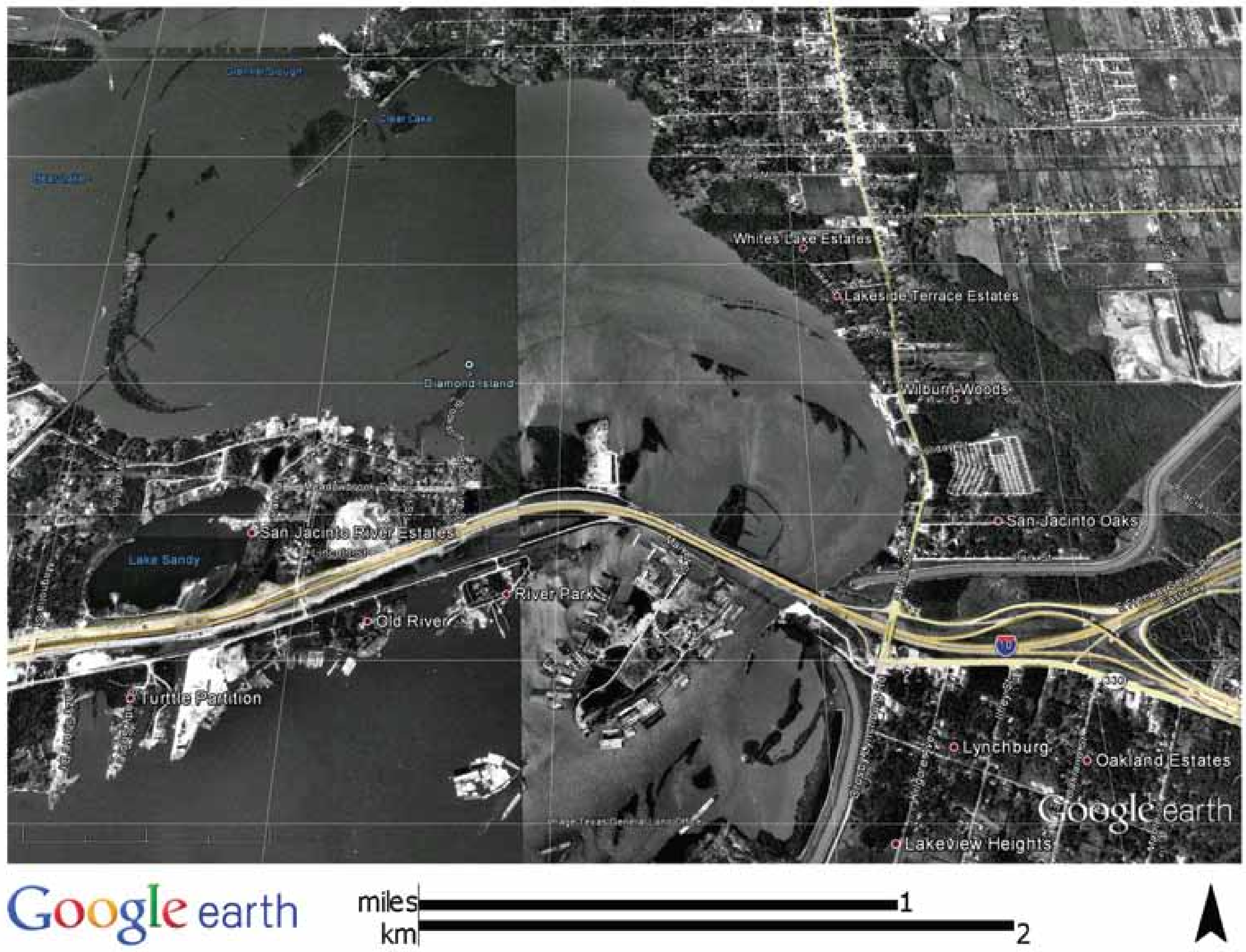


Figure 21. San Jacinto River near the I-10 overcrossing in December 1978

Figure 22. San Jacinto River near the I-10 overcrossing in April 2013

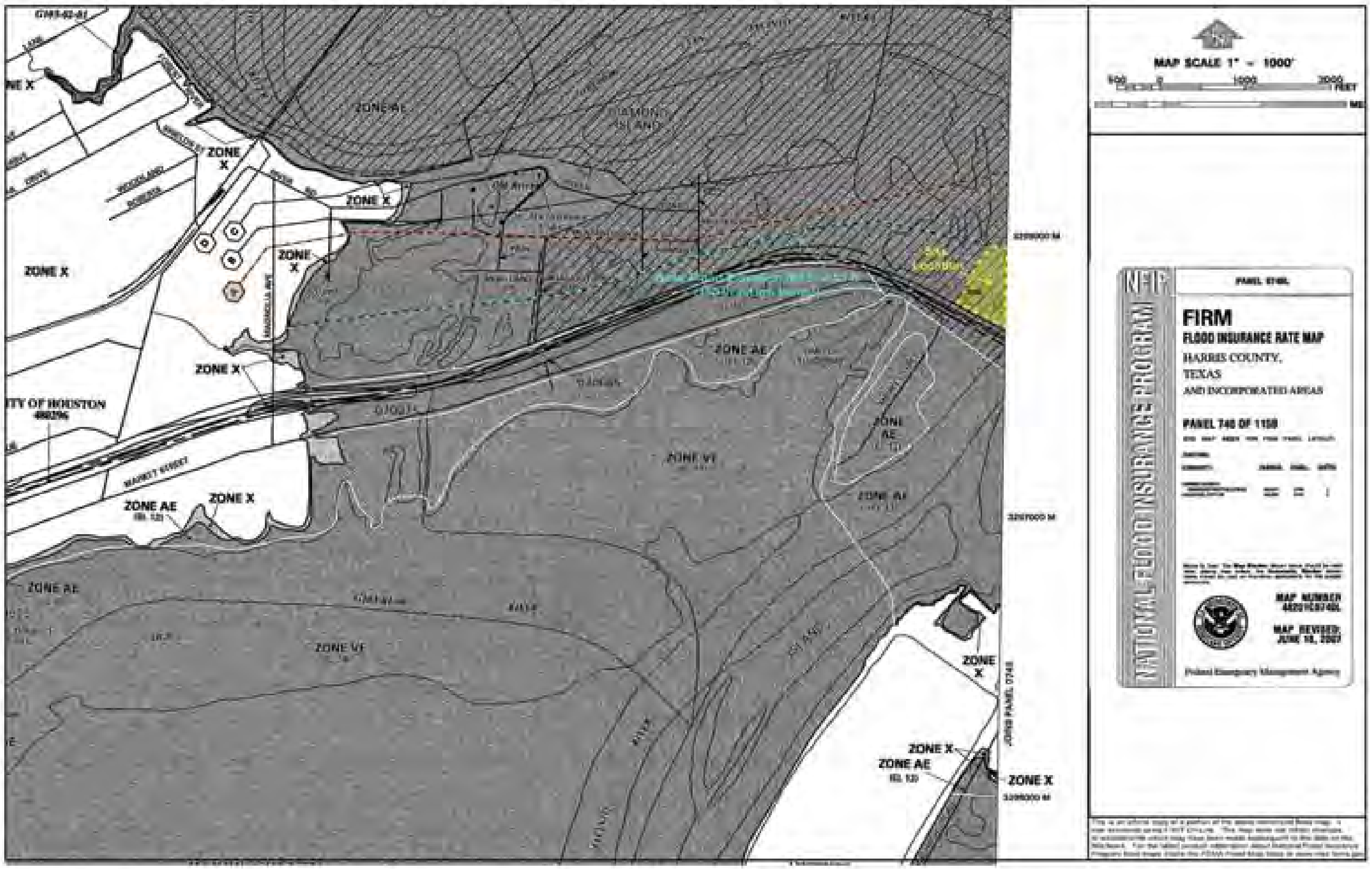


Figure 23. FEMA FIRM near the Inpoundment area showing the base-flood elevation and highlighting Transect A (see Figure 24)

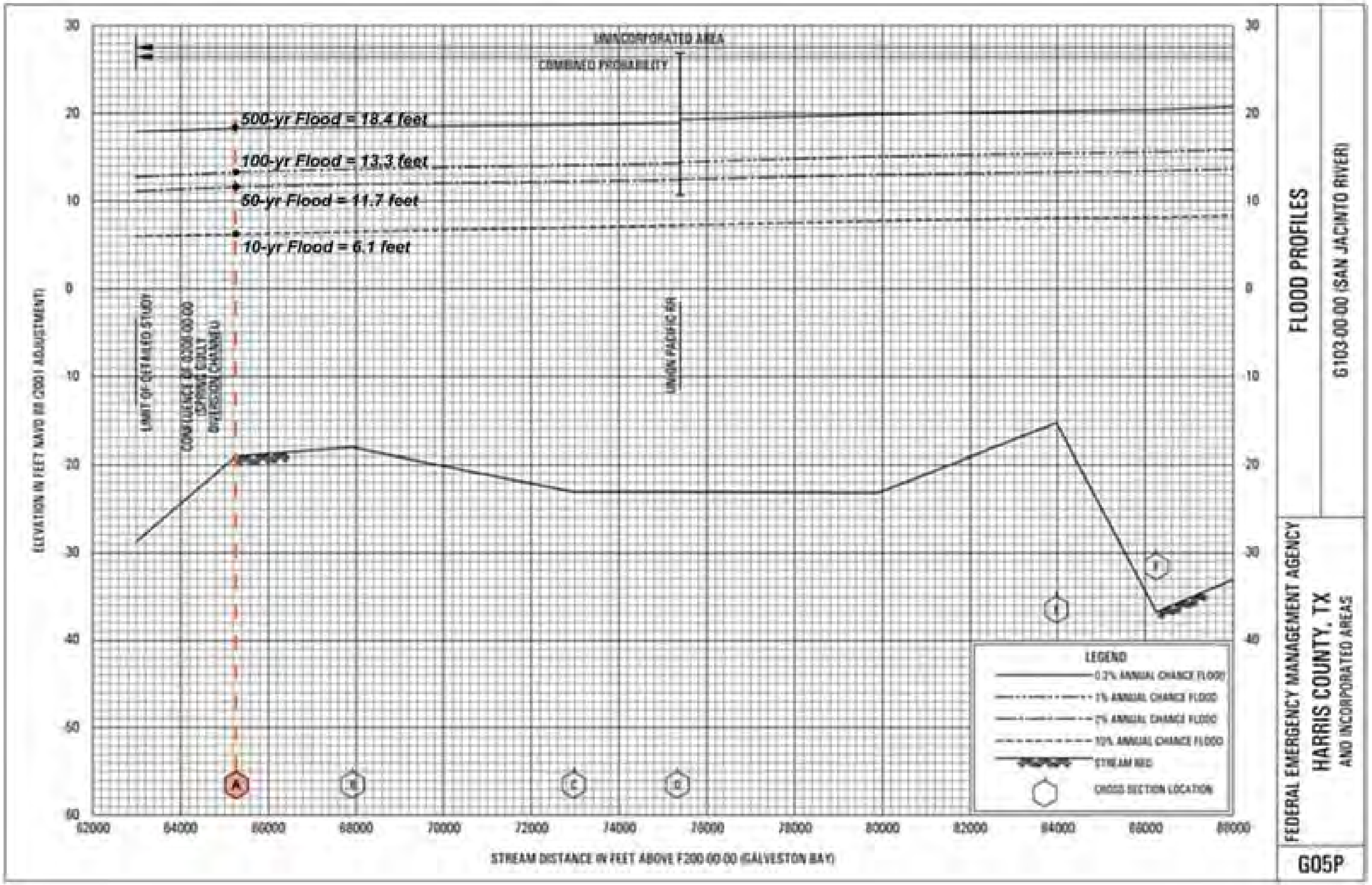


Figure 24. FEMA HEC-RAS model results indicating the magnitudes of various flood events. Transect A corresponds to the dashed orange curve in Figure 23.

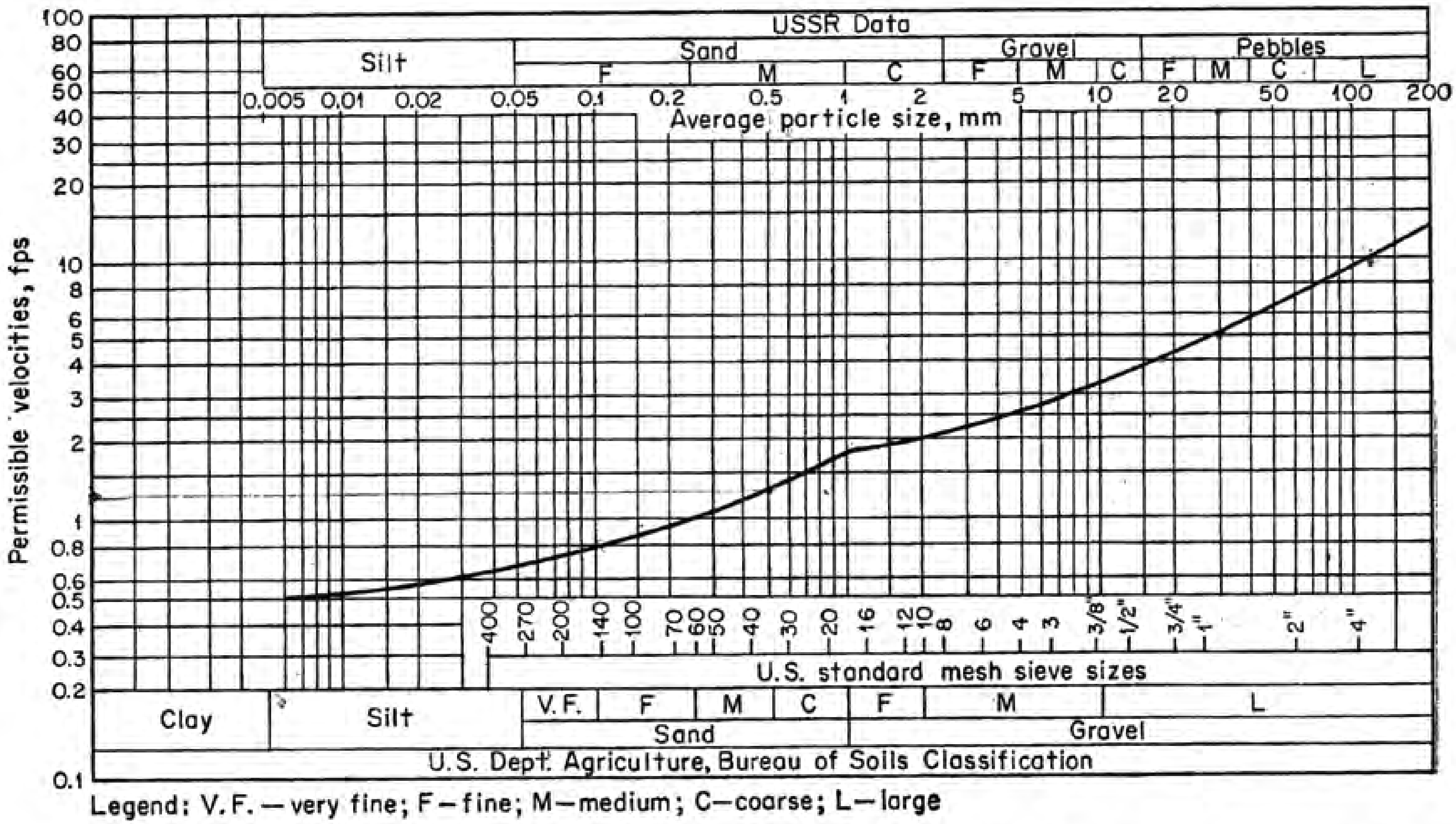


FIG. 7-3. U.S. and U.S.S.R. data on permissible velocities for noncohesive soils.

Figure 25. Permissible velocities for non-cohesive soils (Chow 1959)

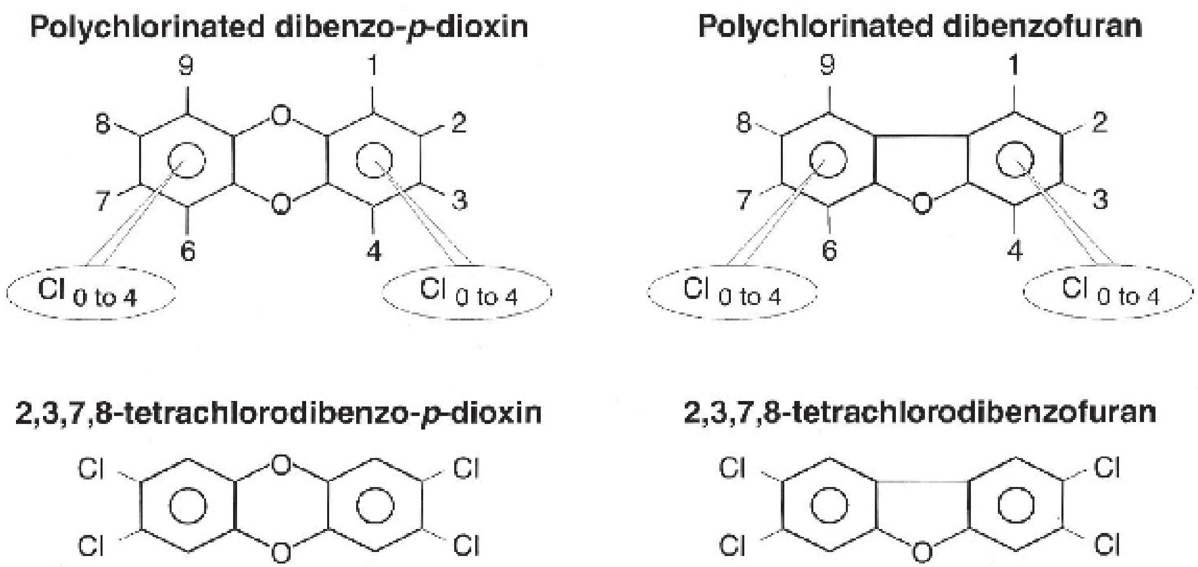


Figure 26. Molecular structure and number system of polychloirnated dibenzo-p-dioxins and dibenzofurans (Shields et al. 2006)

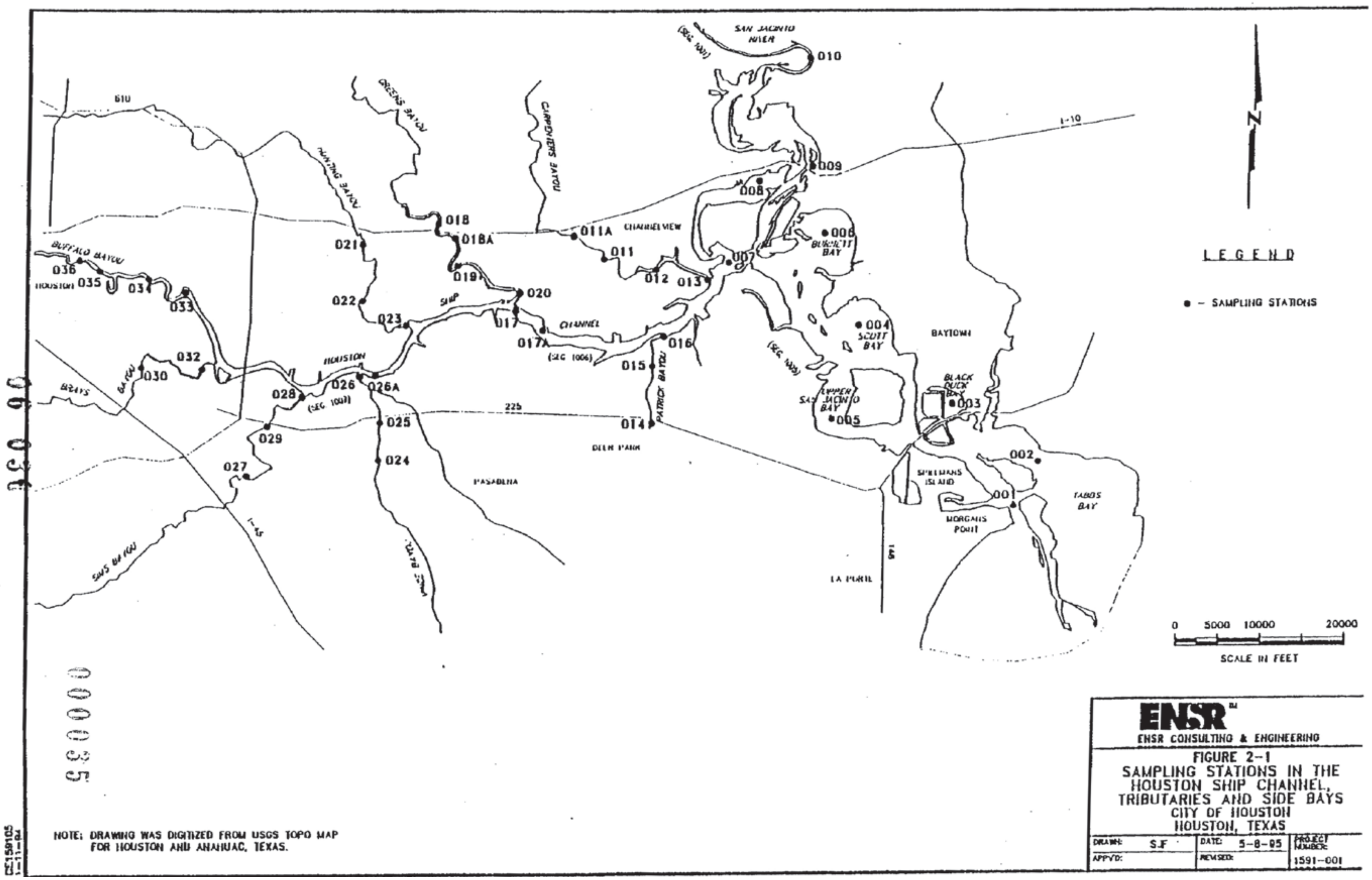


Figure 27. Sampling stations in the Houston Ship Channel tributaries and side bays (Figure 2-1 from ENSR 1995)

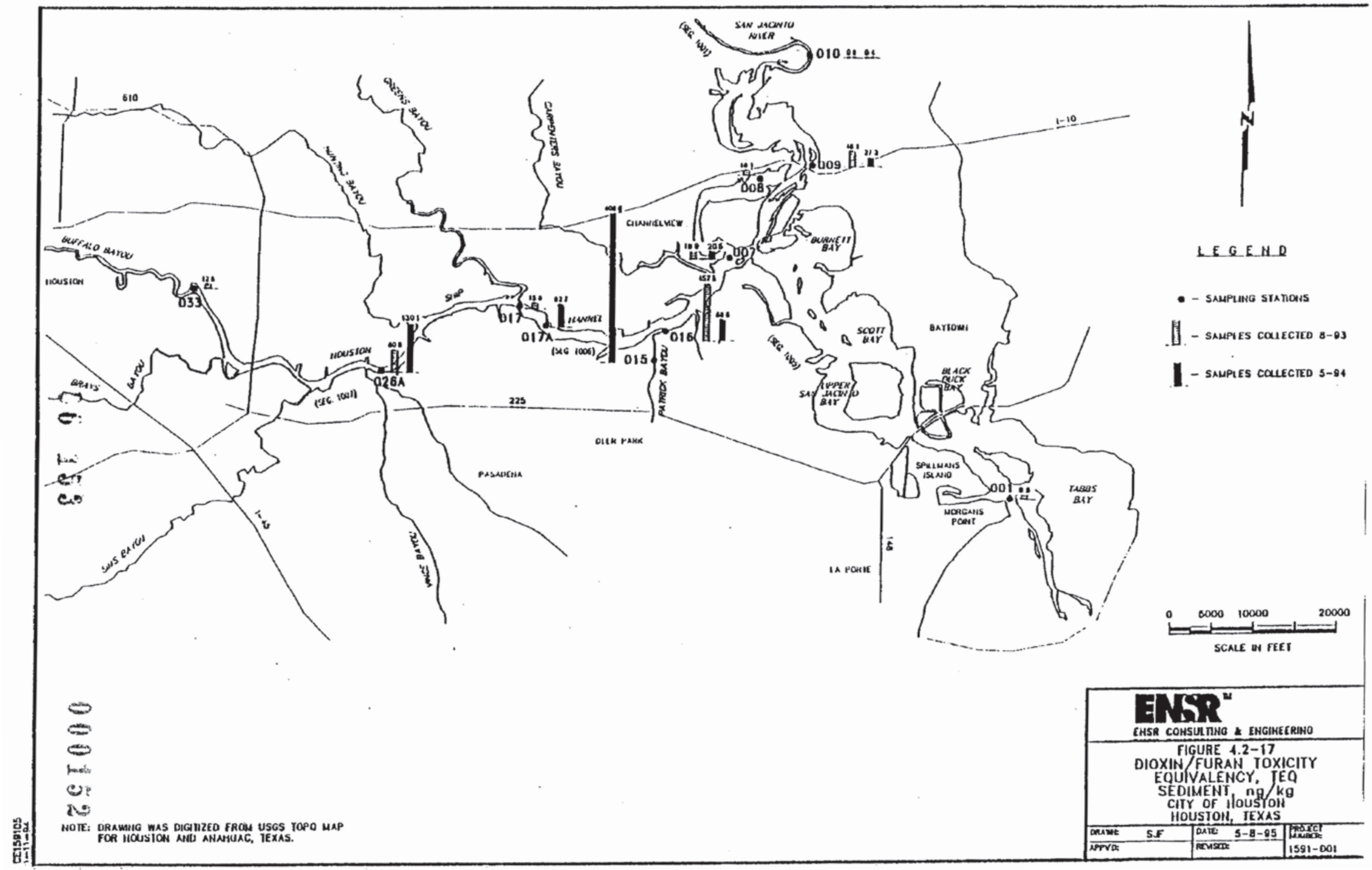


Figure 28. Dioxin/furan toxicity equivalency, TEQ sediment, ng/kg (Figure 4.2-17 from ENSR 1995)

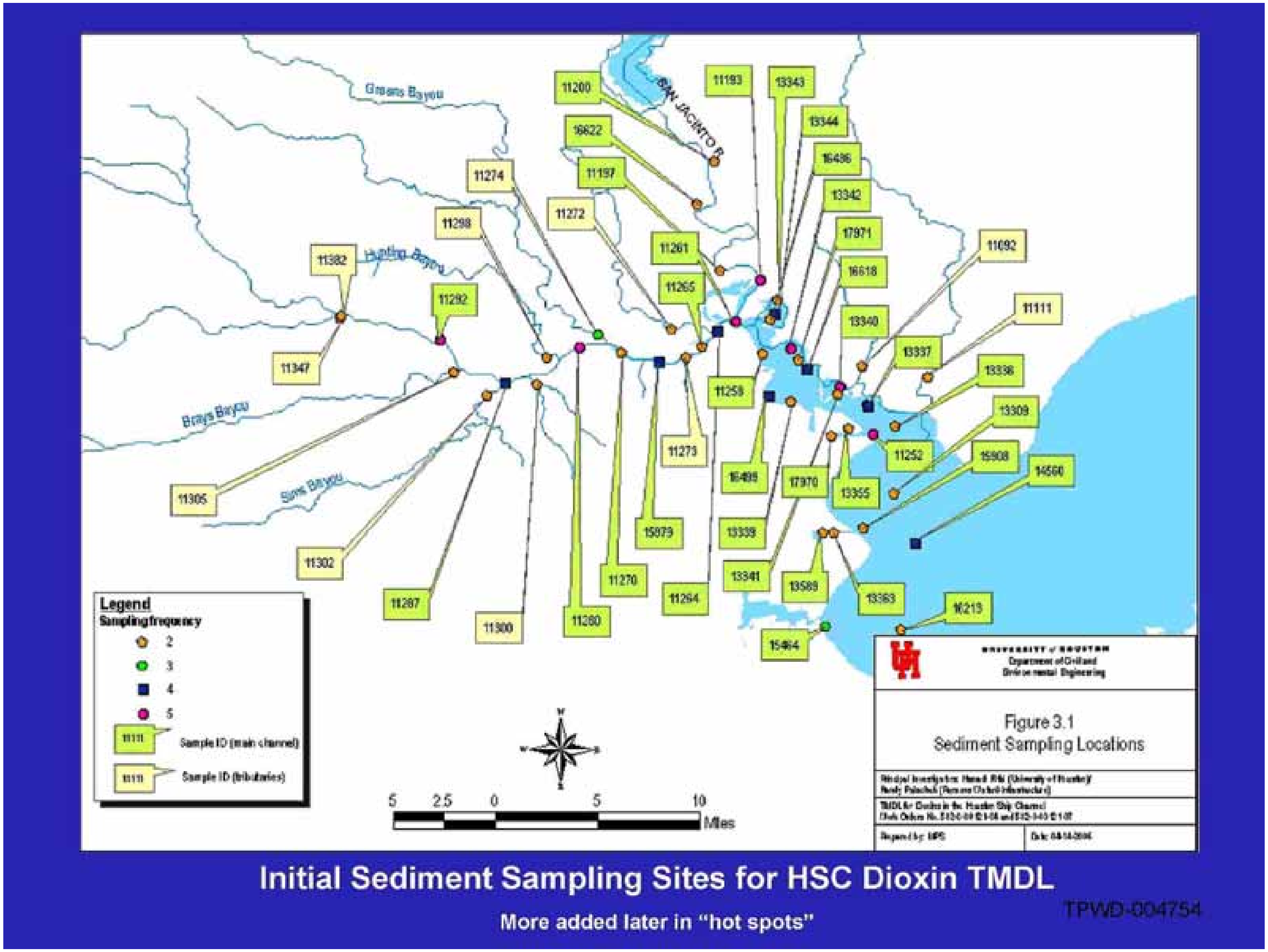


Figure 29. Sediment sampling station locations (Koenig 2009)

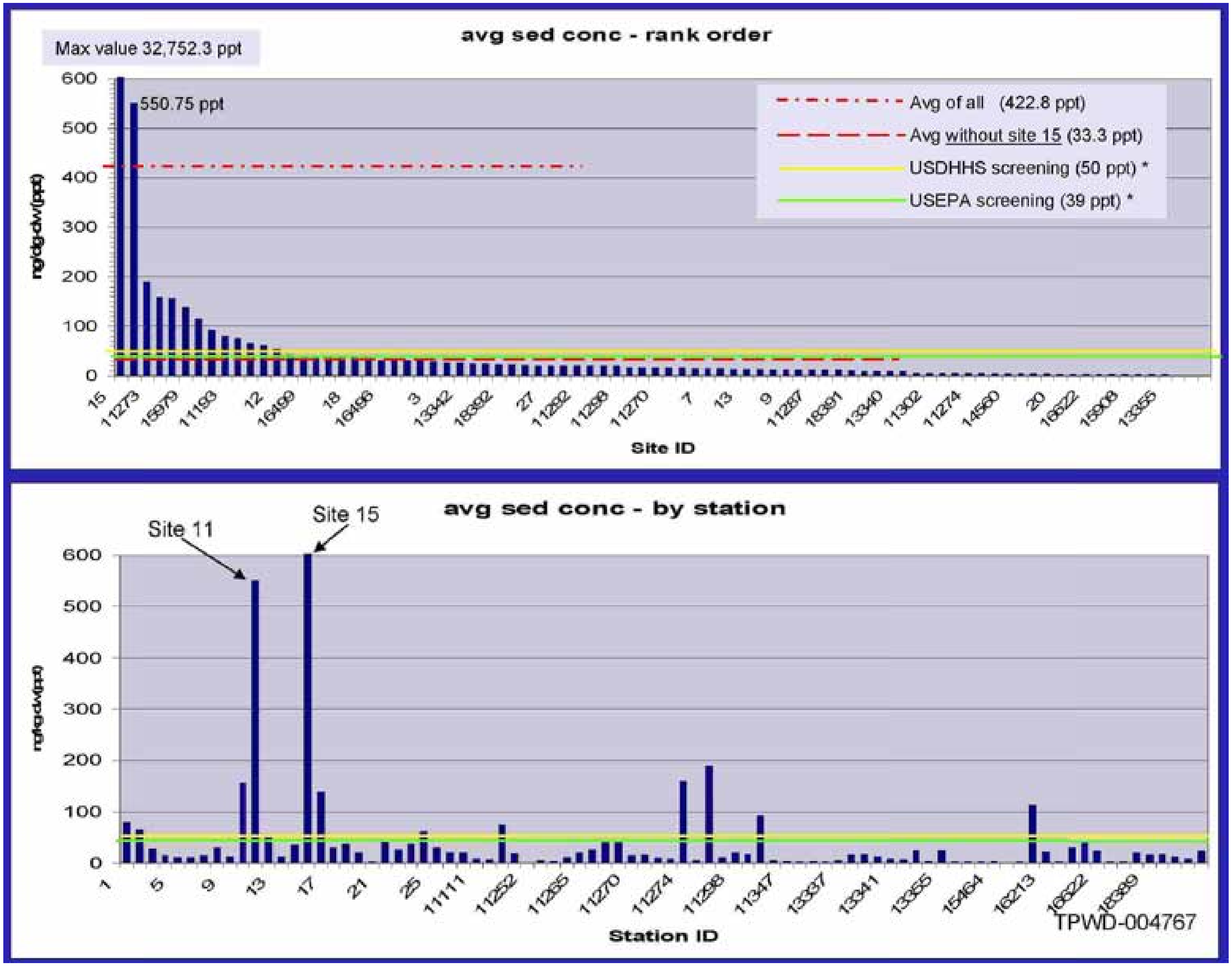


Figure 30. Sediment dioxin concentrations rank ordered by concentration and station (from Koening 2009)

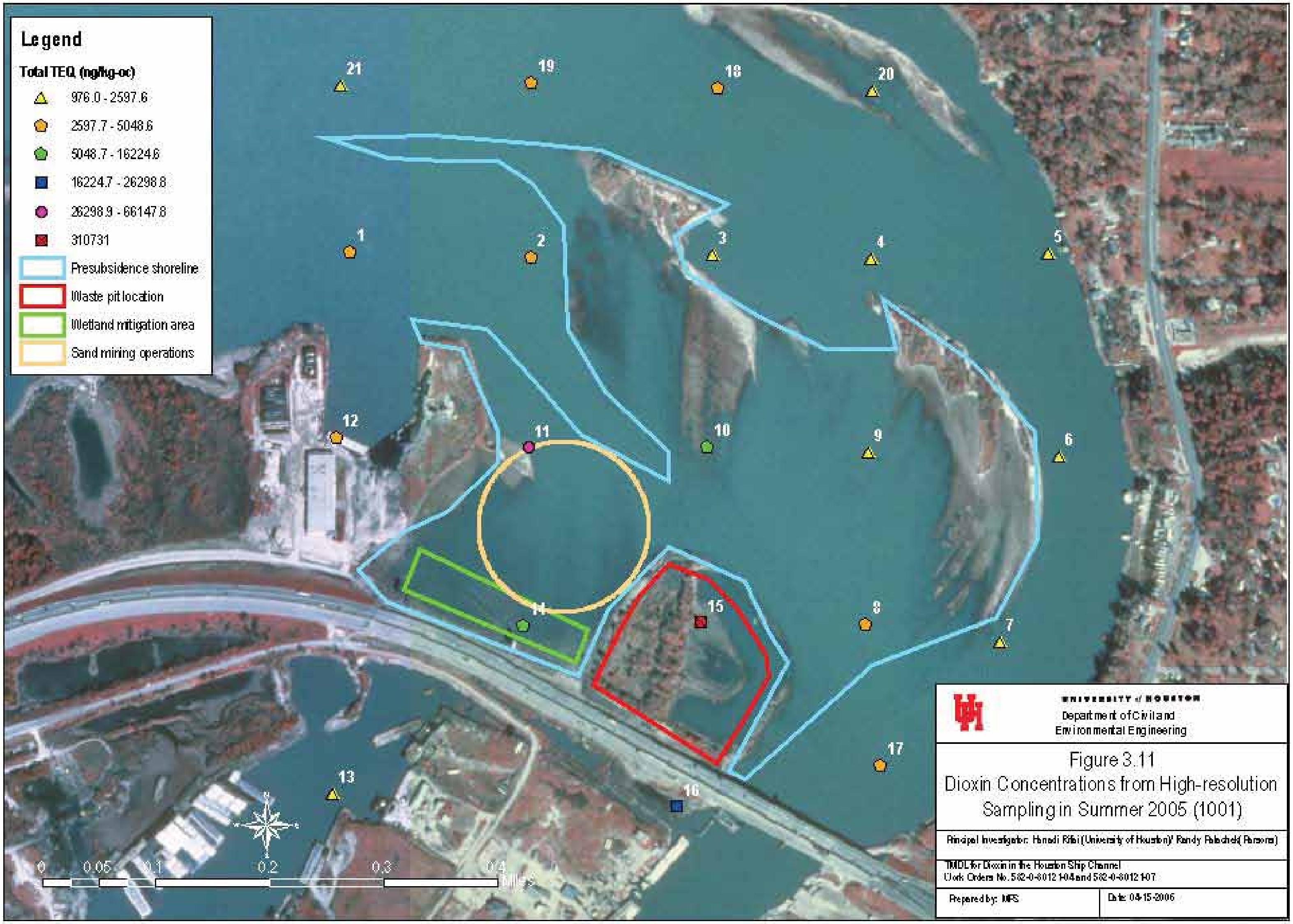


Figure 31. Dioxin concentration from high-resolution sampling in Summer 2005 (OC-normalized) (from Rifai 2006)

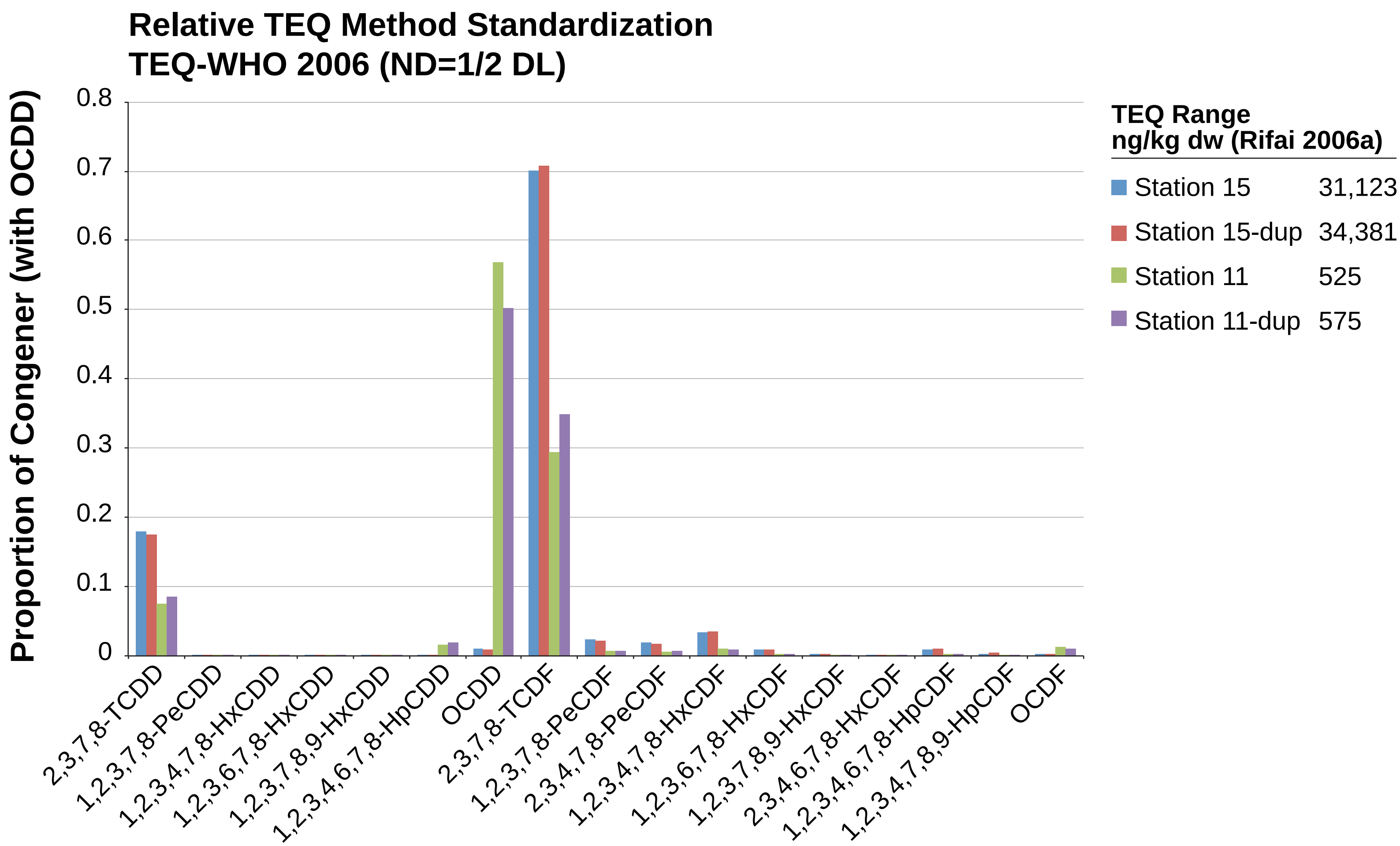


Figure 32. Station 15 and 11 fingerprints summer 2005 (Rifai 2006a)

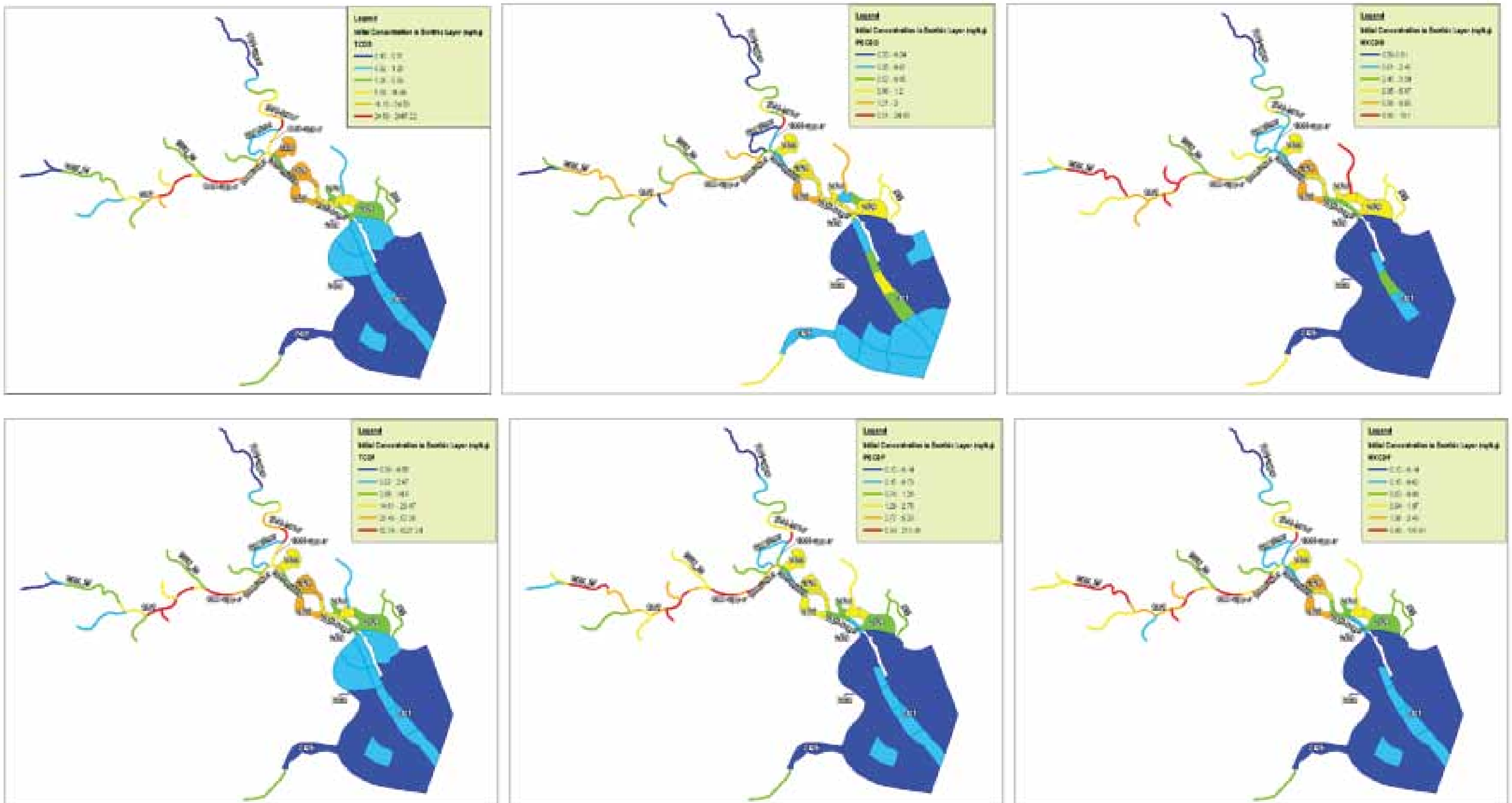
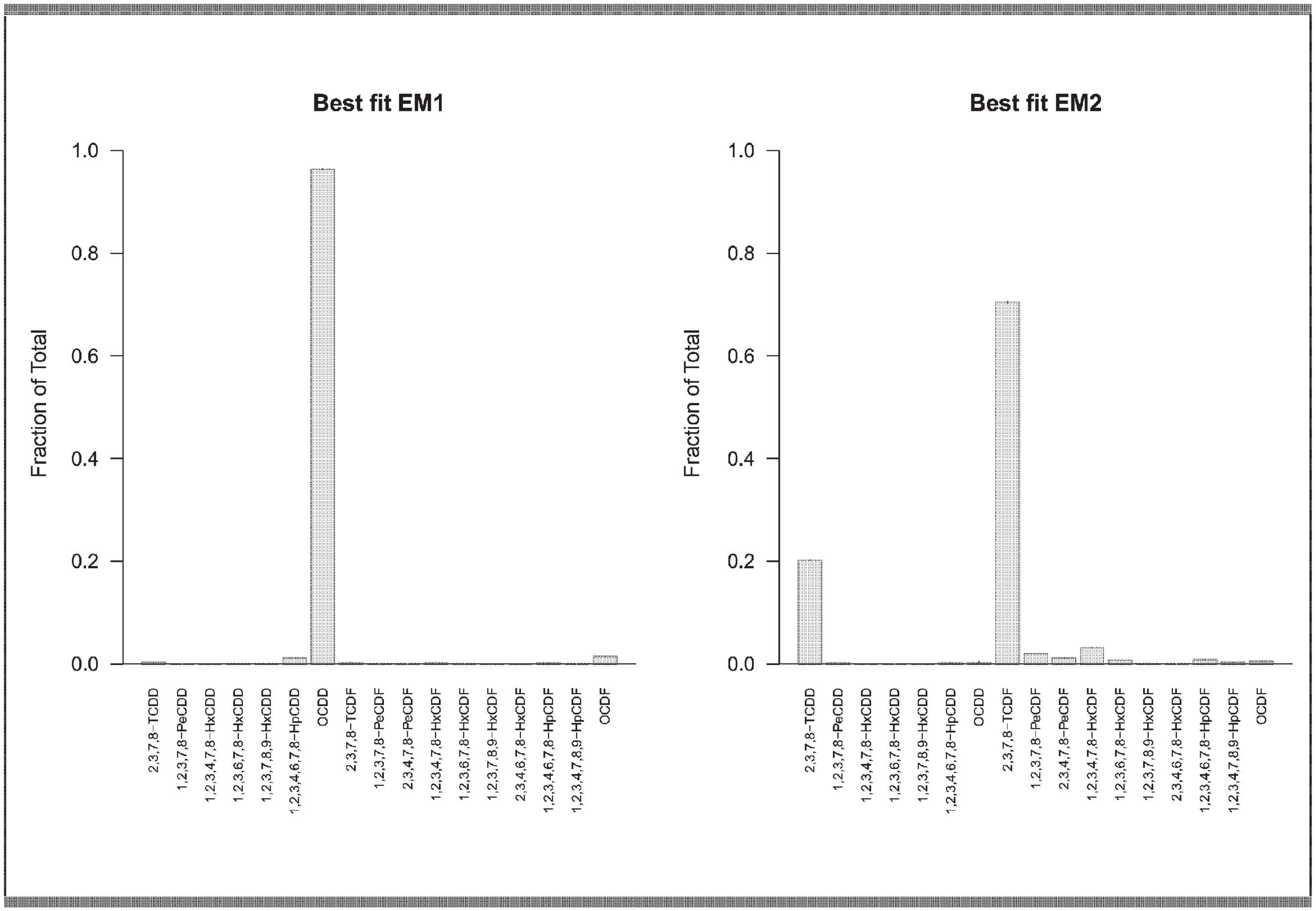


Figure 1 **Distribution of Initial Dioxin Concentrations in Sediment in the WASP Model**

Figure 33. Distribution of initial dioxin concentrations in sediments (ng/kg-dw) for WASP calibration (from Rifai and Palachek 2008)



ANCHOR QEA integral consulting inc.

Figure 6-26
Patterns of Dioxin and Furan Congeners in the End Members of the Best Fit Unmixing Model
SJRWP Preliminary Site Characterization Report
SJRWP Superfund/MIMC and IPC

Figure 34. Patterns of dioxin and furan congeners in the end members of the best fit unmixing model (Integral and Anchor QEA 2012a,b)

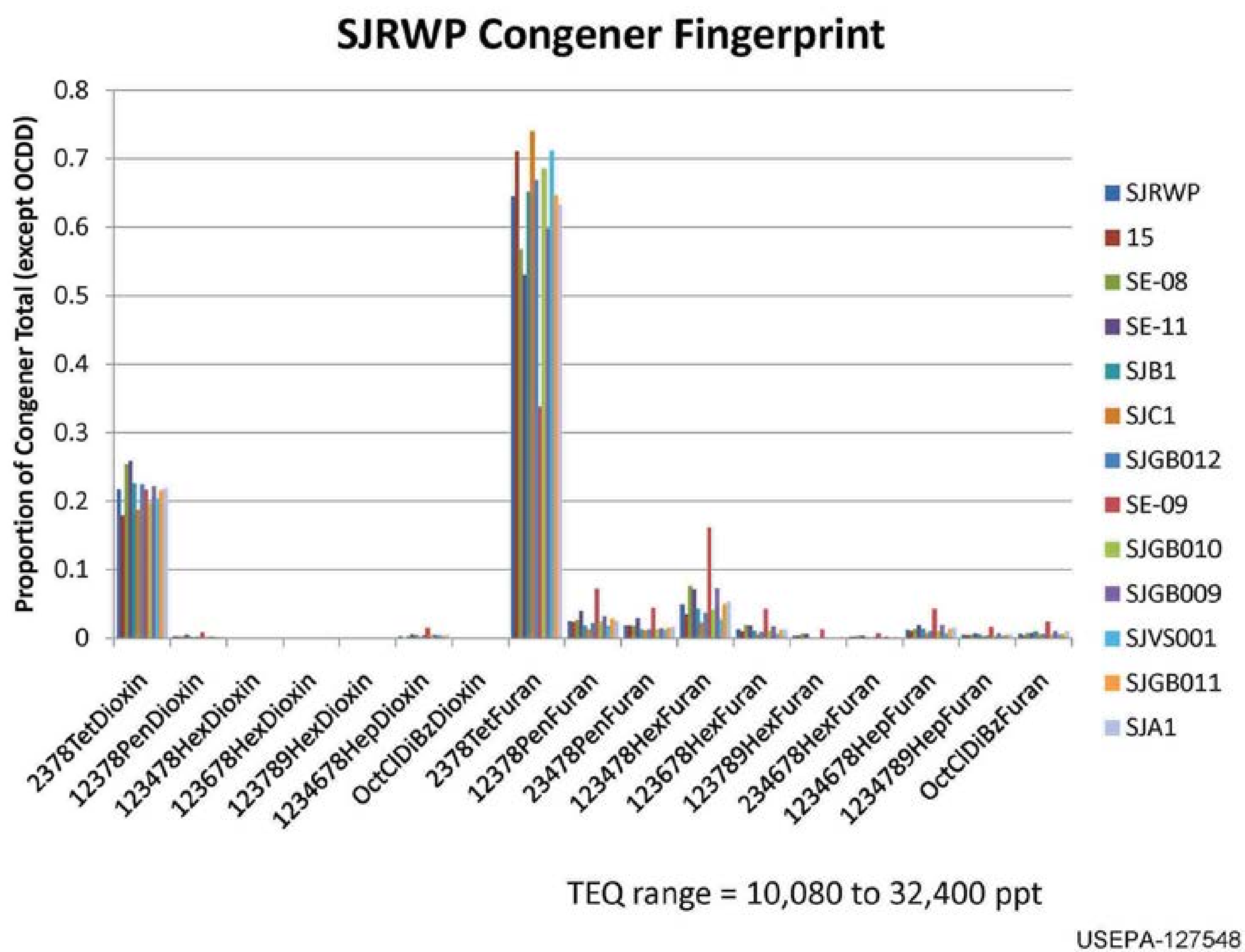


Figure 35. SJRWP congener fingerprint (from Turner and Broach 2011)

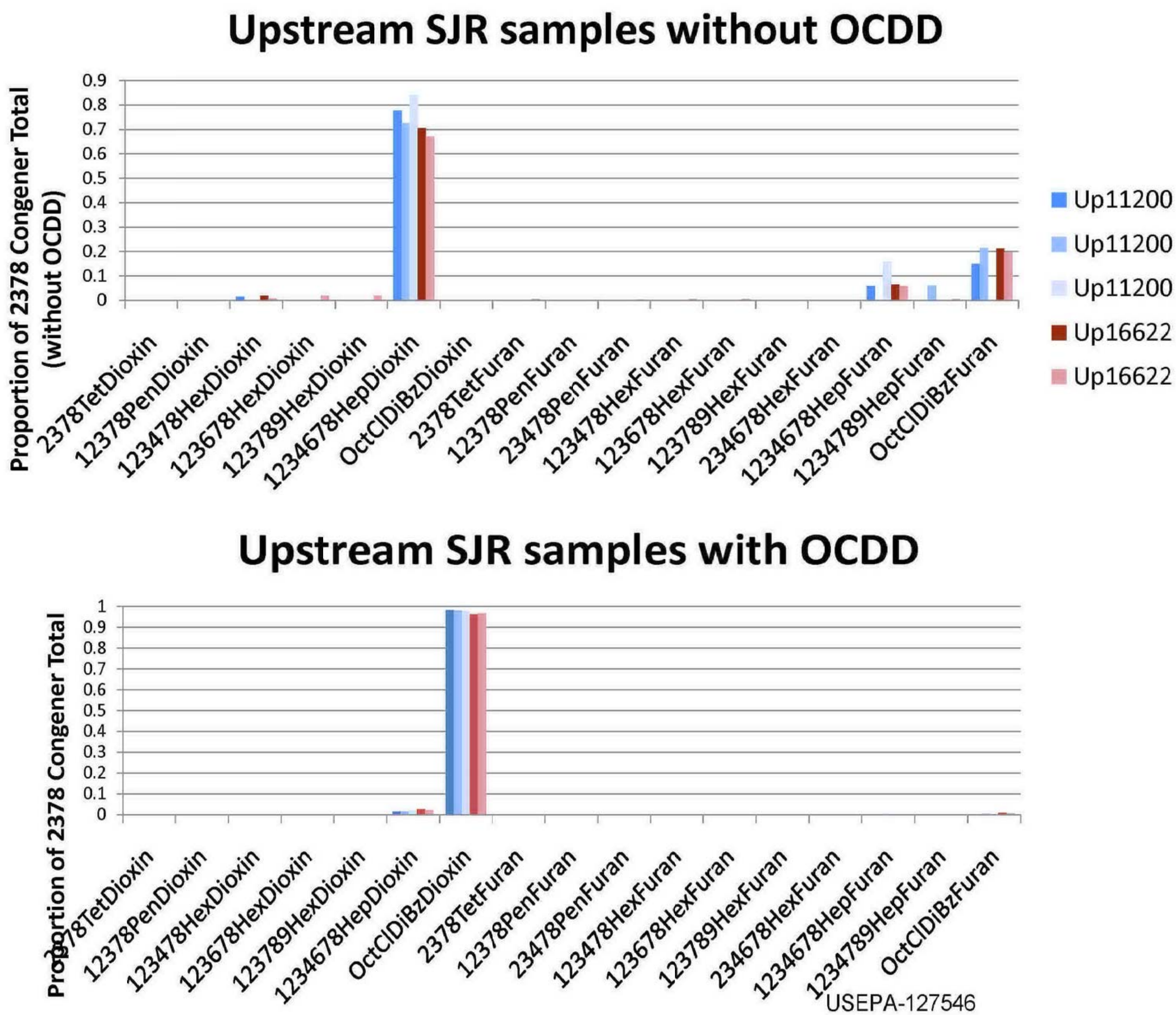


Figure 36. Upstream samples with and without OCDD (from Turner and Broach 2011)

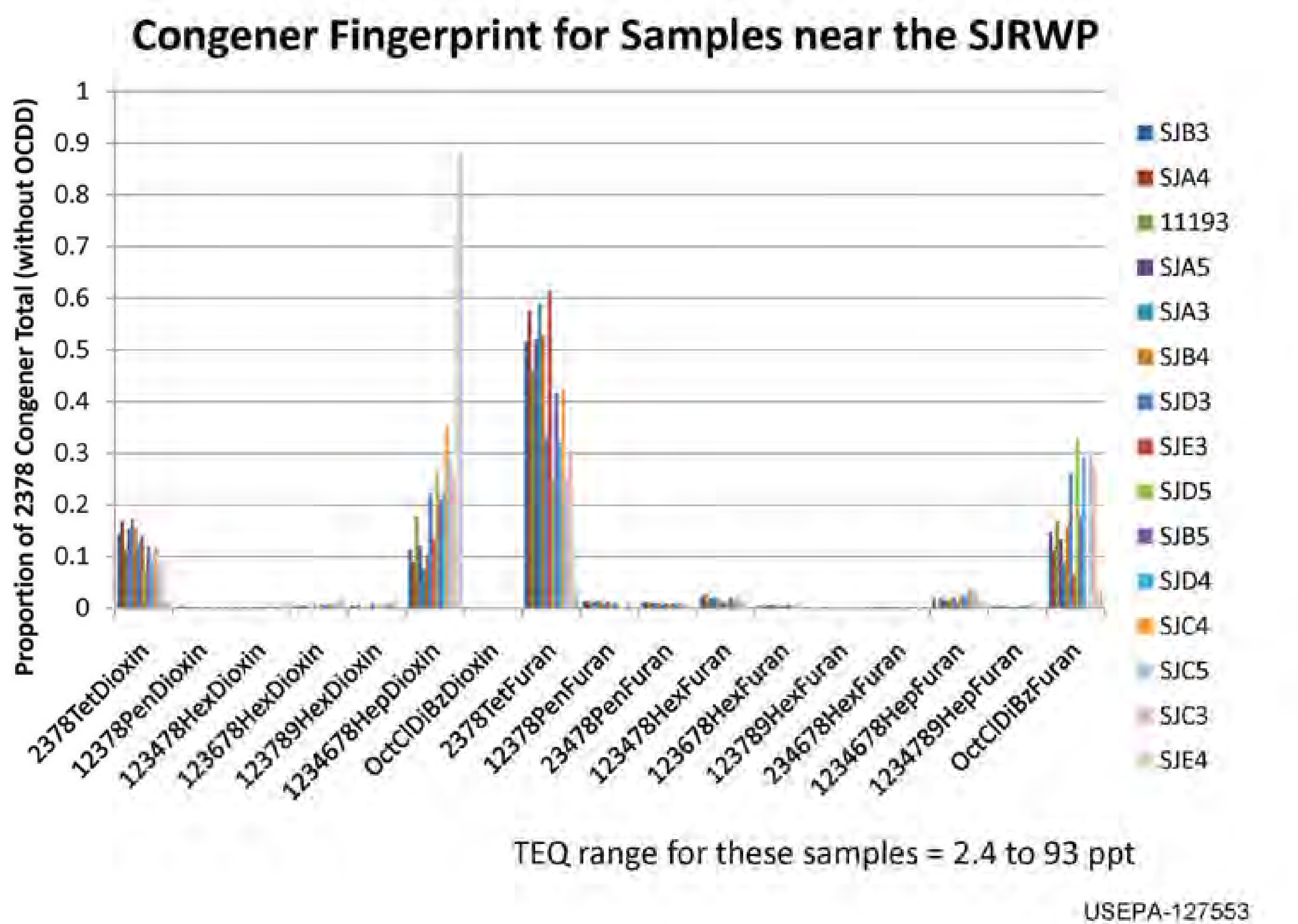


Figure 37. Congener fingerprint (without OCDD) for samples near SJRWP (Impoundments) (Turner and Broach 2011)

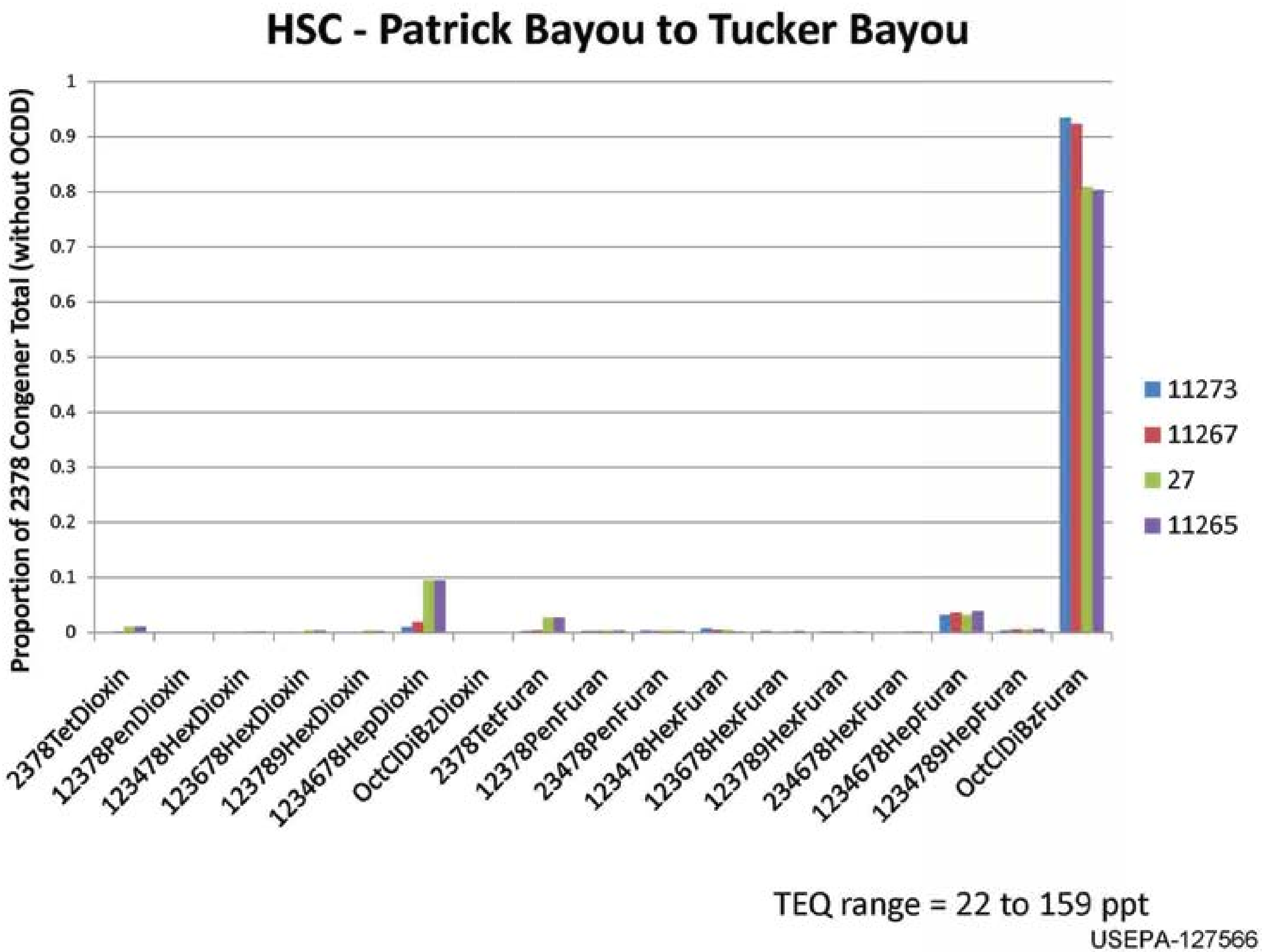


Figure 38. Patrick Bayou to Tucker Bayou, excluding OCDD (from Turner and Broach 2011)

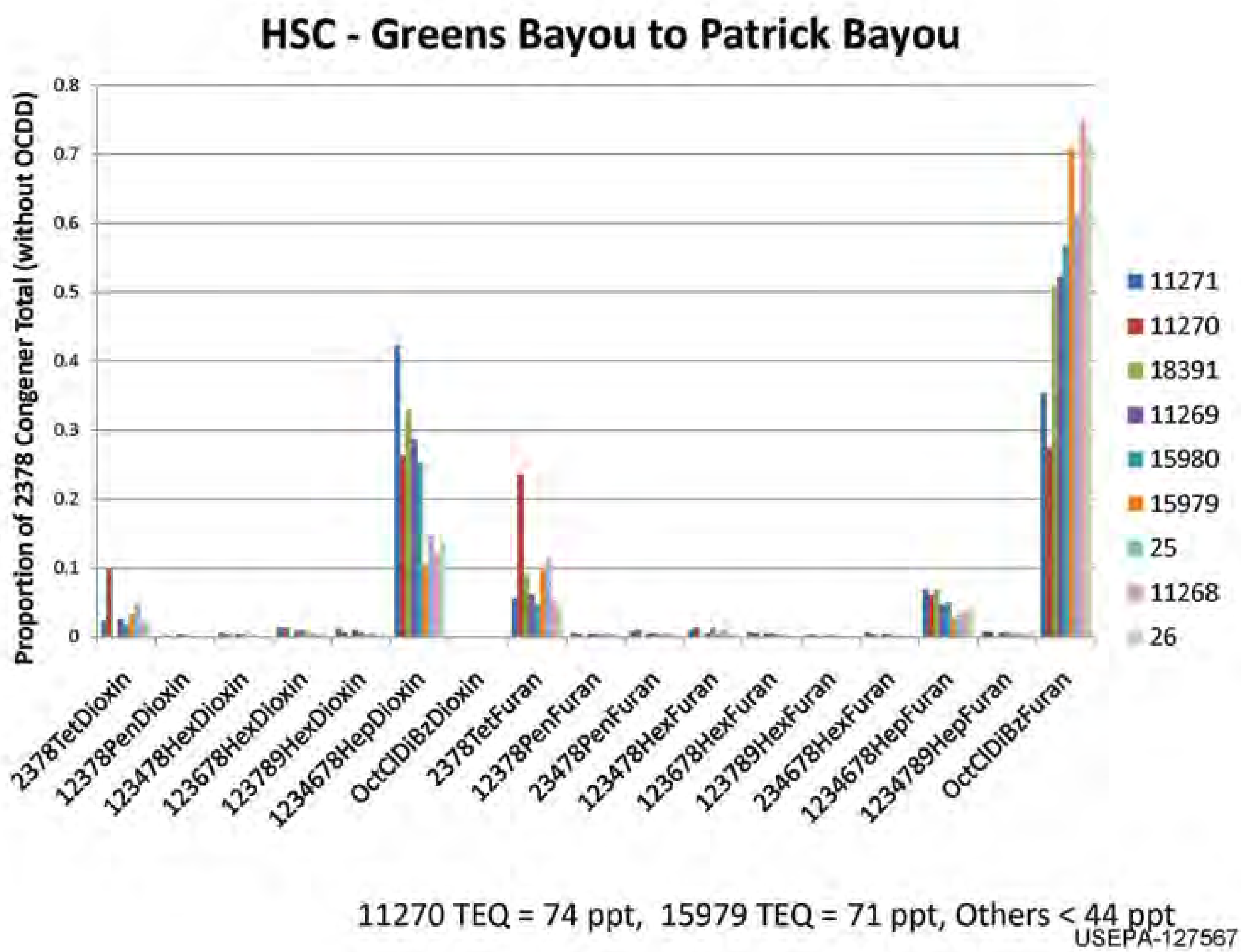
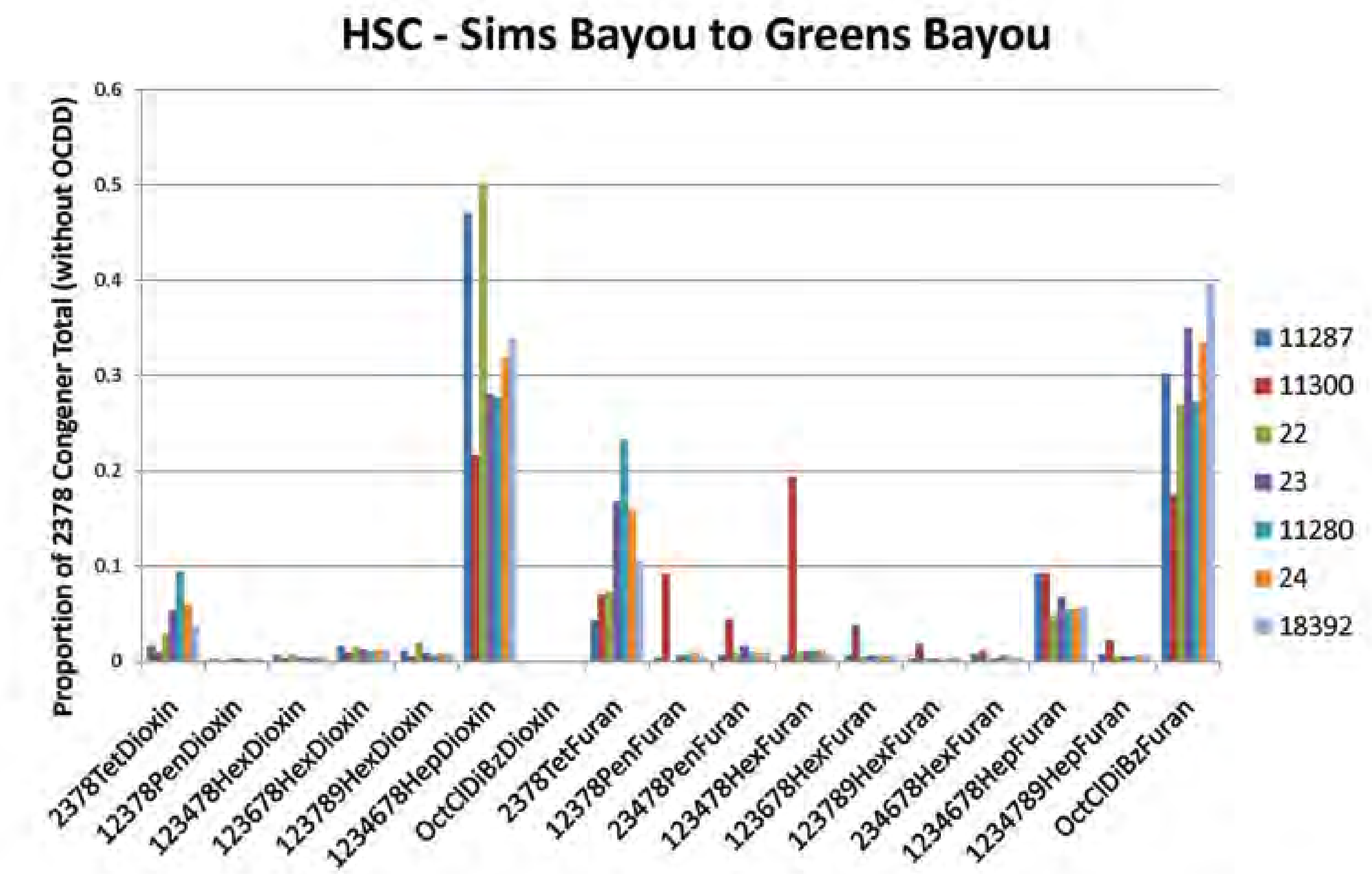


Figure 39. Greens Bayou to Patrick Bayou, excluding OCDD (from Turner and Broach 2011)



11287 TEQ = 14 ppt, 11300 TEQ = 84 ppt 11280 TEQ = 194 ppt, others < 63 ppt

USEPA-127569

Figure 40. Sims Bayou to Greens Bayou, excluding OCDD (from Turner and Broach 2011)

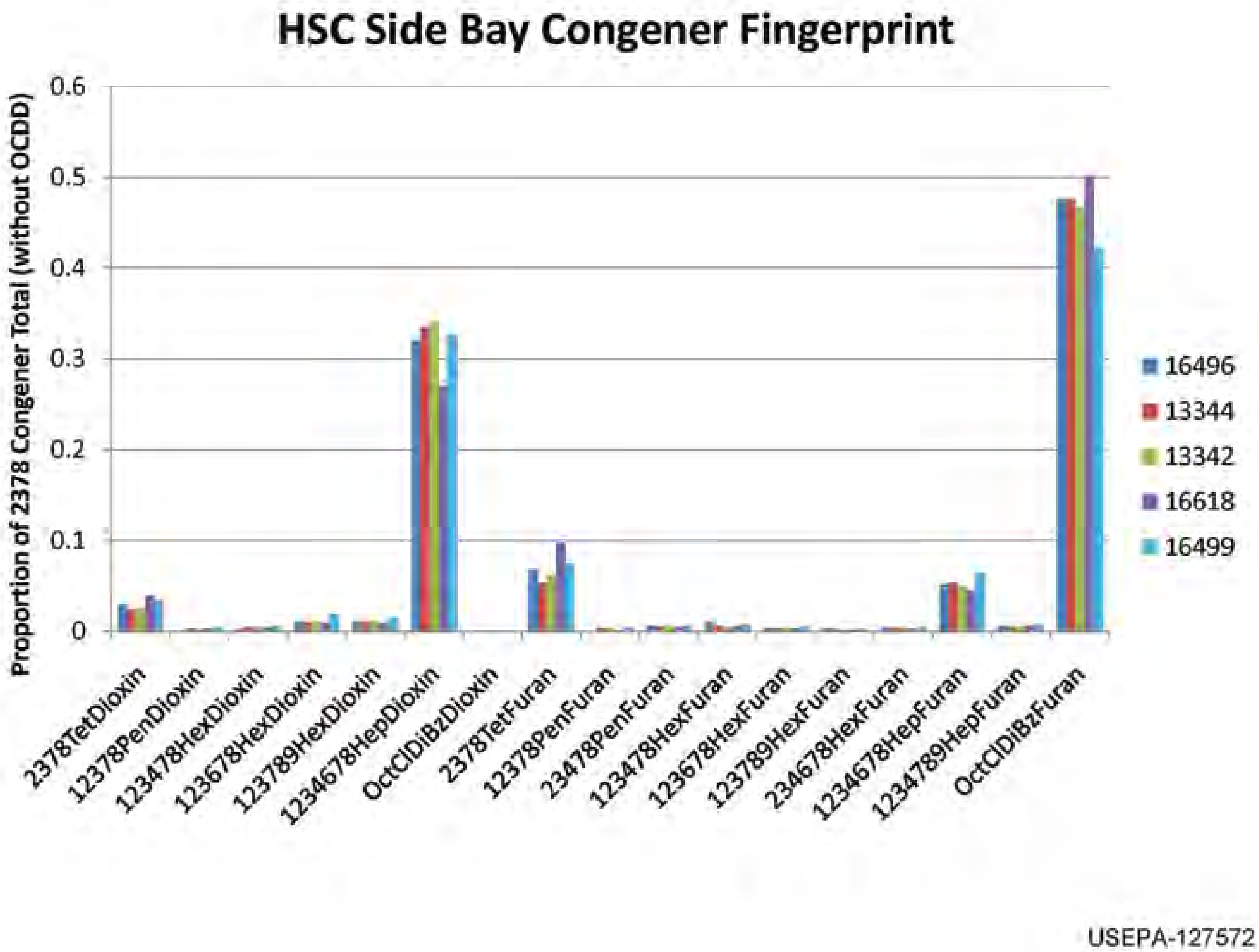


Figure 41. Houston Ship Channel side bay samples, excluding OCDD (from Turner and Broach 2011)

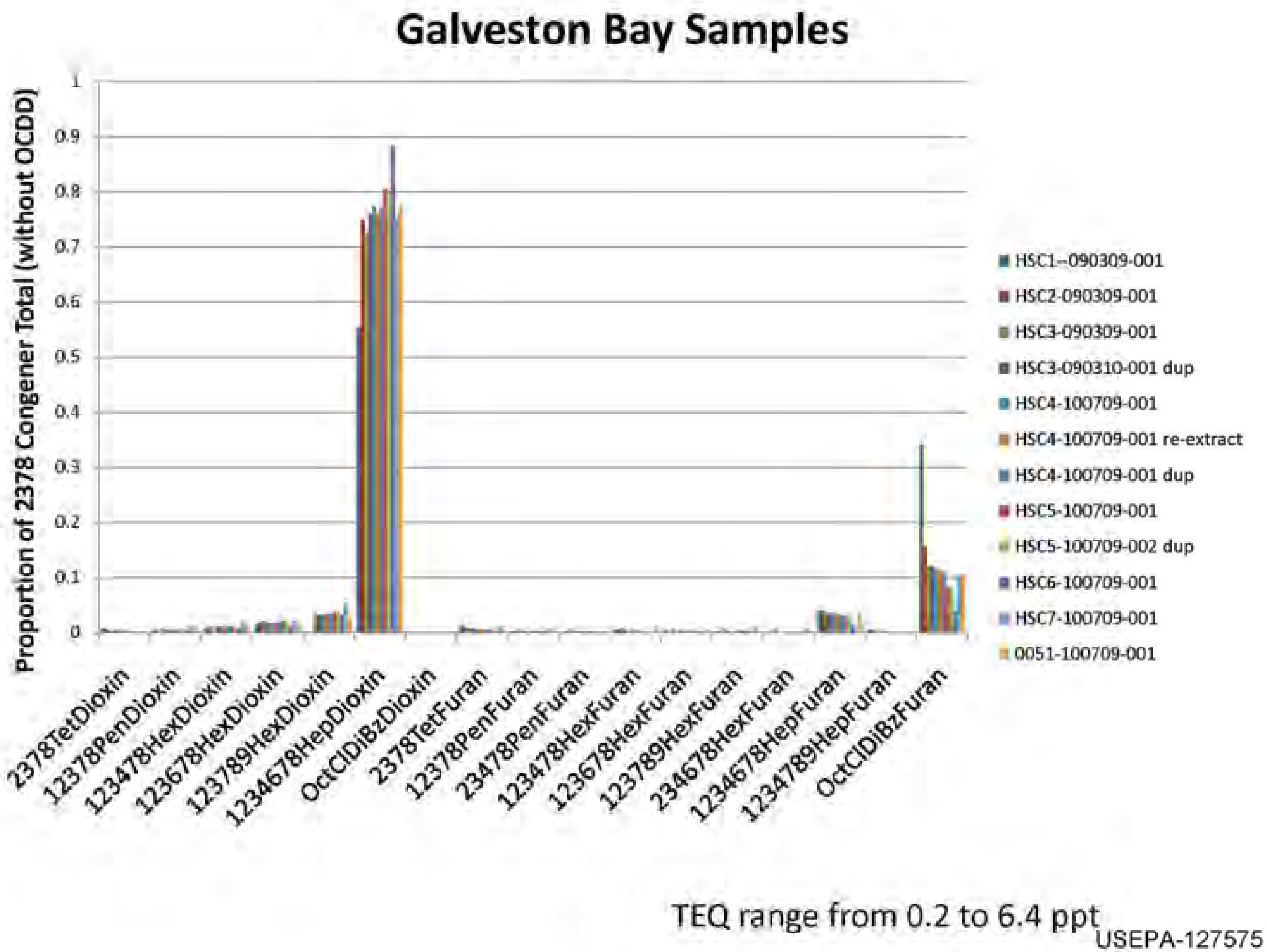


Figure 42. Galveston Bay samples, excluding OCDD (from Turner and Broach 2011)

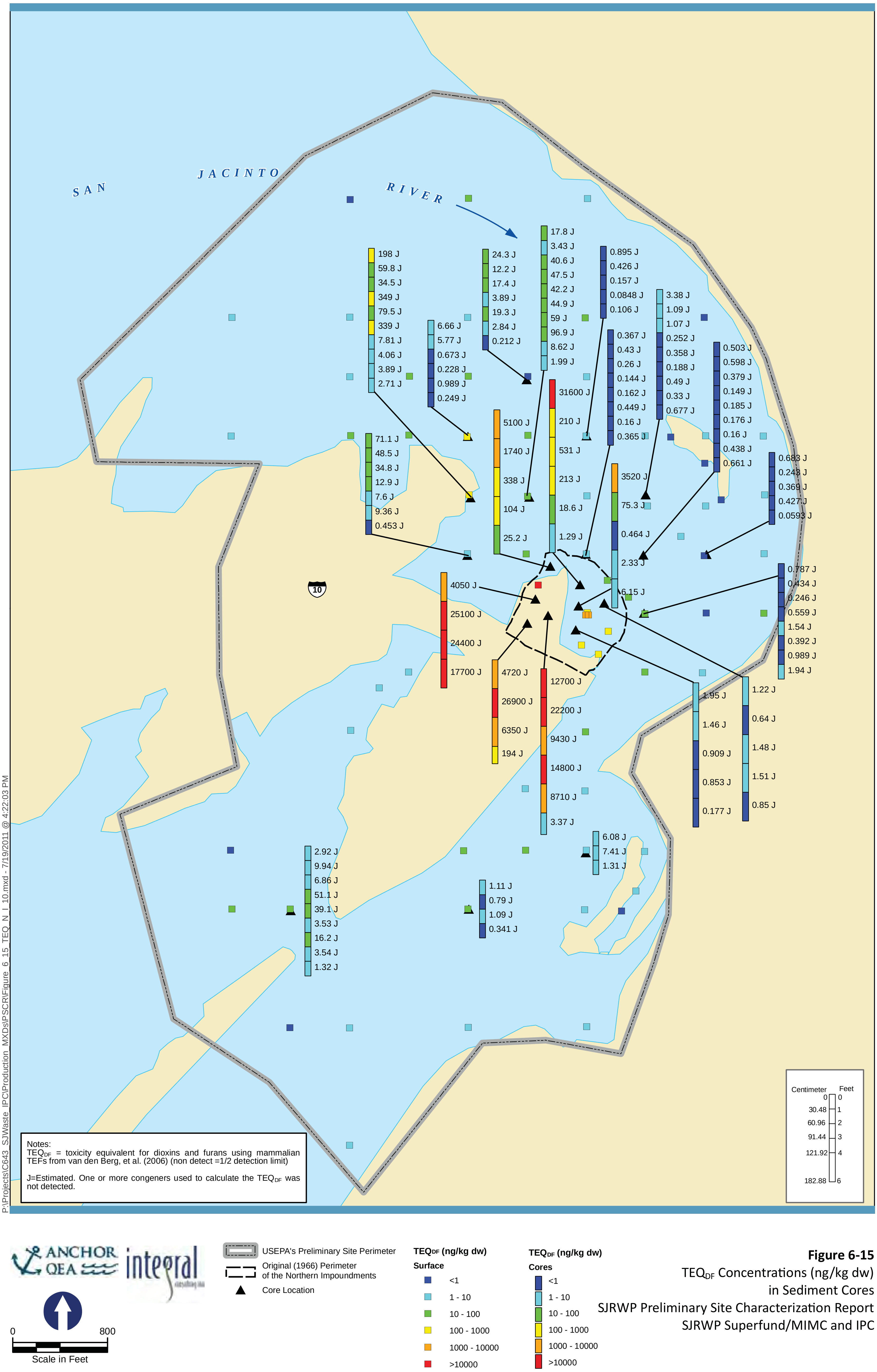


Figure 43. TEQ_{DF} concentrations in sediment cores (Integral Anchor 2012a)

Tables

Table 1. Groundwater velocity estimates

Soil	Hydraulic Conductivity (cm/s)	Porosity (ft^3/ft^3)	Hydraulic Gradient (ft/ft)[a]	Velocity (cm/s; ft/day)
Shallow core SJPERM03	3.81×10^{-6}	0.40^3	1.75×10^{-3}	1.67×10^{-8}; 4.73×10^{-5}
Shallow core SJPERM01	1.05×10^{-6}	0.40^3	1.75×10^{-3}	4.59×10^{-9}; 1.30×10^{-5}
Shallow core SJPERM02	8.39×10^{-7}	0.40^3	1.75×10^{-3}	3.67×10^{-9}; 1.40×10^{-5}

[a] Calculated from Integral and Anchor QEA (2012a,b, Fig. 6-7).

Table 2. Median particle sizes from various sediment samples

Sample	d_{50} (mm)	Classification
Beach area A	0.3763	Silty loam
Beach area B/C	0.5156	Silty loam
Beach area D	0.5123	Silty loam
Beach area E	0.4048	Silty loam

Table 3. Stage and date of historical floods in the San Jacinto River near Sheldon

Sorted by Stage		Sorted by Date	
Stage (ft)	Date	Stage (ft)	Date
32.9	5/1/1929	32.9	5/1/1929
31.5	11/16/1940	31.5	11/16/1940
27.09	10/19/1994	20.12	6/15/1973
20.12	6/15/1973	11.58	3/19/1981
20.1	5/19/1989	10.33	5/15/1982
19.61	11/15/1998	17.5	5/23/1983
17.5	5/23/1983	12.6	11/27/1985
16.36	6/10/2001	11.9	6/13/1987
16.36	10/20/1998	20.1	5/19/1989
15	11/7/2002	10.57	6/13/1989
14.8	6/22/1993	8.8	1/20/1991
14.39	9/13/2008	12.03	3/5/1992
13.9	6/23/1993	14.8	6/22/1993
13.5	10/29/2002	13.9	6/23/1993
13.19	1/9/1998	27.09	10/19/1994
12.6	11/27/1985	10.01	1/28/1995
12.03	3/5/1992	7.53	3/13/1997
11.9	6/13/1987	13.19	1/9/1998
11.74	11/18/2003	16.36	10/20/1998
11.58	3/19/1981	19.61	11/15/1998
10.64	4/29/2009	16.36	6/10/2001
10.57	6/13/1989	13.5	10/29/2002
10.33	5/15/1982	15	11/7/2002
10.23	10/17/2006	11.74	11/18/2003
10.01	1/28/1995	10.23	10/17/2006
8.8	1/20/1991	14.39	9/13/2008
7.53	3/13/1997	10.64	4/29/2009

Table 4. Homologue classes of PCDD/PCDFs

Homologue Class	Abbreviation	Chlorines	Number of Isomers
Polychlorinated Dibenzo-*p*-dioxins (PCDDs)			
Monochlorodibenzo-*p*-dioxins	MCDD	1	2
Dichlorodibenzo-*p*-dioxins	DCDD	2	10
Trichlorodibenzo-*p*-dioxins	TrCDD	3	14
Tetrachlorodibenzo-*p*-dioxins	TCDD	4	22
Pentachlorodibenzo-*p*-dioxins	PeCDD	5	14
Hexachlorodibenzo-*p*-dioxins	HxCDD	6	10
Heptachlorodibenzo-*p*-dioxins	HpCDD	7	2
Octachlorodibenzo-*p*-dioxin	OCDD	8	1
Total			**75**
Polychlorinated Dibenzofurans (PCDFs)			
Monochlorodibenzofurans	MCDF	1	4
Dichlorodibenzofurans	DCDF	2	16
Trichlorodibenzofurans	TrCDF	3	28
Tetrachlorodibenzofurans	TCDF	4	38
Pentachlorodibenzofurans	PeCDF	5	28
Hexachlorodibenzofurans	HxCDF	6	16
Heptachlorodibenzofurans	HpCDF	7	4
Octachlorodibenzofuran	OCDF	8	1
Total			**135**

Table 5. 2,3,7,8-substituted PCDD/PCDF congeners, TEFs, and homologue classes

Congener	NAT0-89 I-TEFs	WH0-98 TEFs	WHO-05 TEFs	Homologue Class
2,3,7,8-TCDD	1	1	1	Total TCDDs
1,2,3,7,8-PeCDD	0.5	1	1	Total PeCDDs
l,2,3,4,7,8-HxCDD	0.1	0.1	0.1	Total HxCDDs
1,2,3,6,7,8-HxCDD	0.1	0.1	0.1	
1,2,3,7,8,9-HxCDD	0.1	0.1	0.1	
l,2,3,4,6,7,8-HpCDD	0.1	0.01	0.01	Total HpCDDs
OCDD	0.001	0.0001	0.0003	OCDD
2,3,7,8-TCDF	0.1	0.1	0.1	Total TCDFs
1,2,3,7,8-PeCDF	0.05	0.05	0.03	Total PeCDFs
2,3,4,7,8-PeCDF	0.5	0.5	0.3	
1,2,3,4,7,8-HxCDF	0.1	0.1	0.1	Total HxCDFs
1,2,3,6,7,8-HxCDF	0.1	0.1	0.1	
1,2,3,7,8,9-HxCDF	0.1	0.1	0.1	
2,3,4,6,7,8-HxCDF	0.1	0.1	0.1	
1,2,3,4,6,7,8-HpCDF	0.01	0.01	0.01	Total HpCDFs
1,2,3,4,7,8,9-HpCDF	0.01	0.01	0.01	
OCDF	0.001	0.0001	0.0003	OCDF

Notes: TEF - toxicity equivalence factor
NAT0-89 - refers to the so-called "international TEFs" (I-TEFs) reported in NATO/CCMS (1988)
WH0-98 - refers to the World Health Organization TEFs (WHO-TEFs) reported in Van den Berg et al. (1998)

Table 6. Dioxin/furan concentrations in sediment samples (ng/kg) (from ENSR 1995, Table 3.2-12)

	Main Channel								San Jacinto River					Patrick Bayou		
	HSC at Morgans Point	HSC at San Jacinto Monument	HSC at San Jacinto Monument	Down-stream Green's Bayou	Down-stream of Green's Bayou	Mouth Vince Bayou	Mouth Vince Bayou	HSC at turning basin	Mouth	Middle	Middle	Up-stream	Up-stream	Middle	Mouth	Mouth
Parameter	001[a]	007[a]	007[b]	017[a]	017A[b]	026A[a]	026A[b]	033[a]	008[a]	009[a]	009[b]	010[a]	010[b]	015[b]	016[a]	016[b]
2,3,7,8-TCDD	2.4	9.2	8.5	7.2	42.1	28.1	75.5	0.38	10.1	27.8	12.5			3.1	93.6	22.6
2,3,7,8-TCDF	6.9	22.9	26.4	21.7	104	89	296		29.9	73.3	33.4			83.6	290	74.3
Total TCDD	3.3	16.7	16.5	7.2	51.2	37.9	91.7	2.3	14.9	33.8	20.2			12.3		32.7
Total TCDF	11.2	38.1	53.9	30.5	227	186	576	2	56.4	168	67.2			432		229
Total PeCDD	22.7	15	17.4	1.3	1.4	1.6	4		3.7	8.9	12.8			115		9.6
Total PeCDF	4.5	8	10.5	4.2	26.6	87.2	101	40.7	12.4	28.7	19.9			1,390		103
Total HxCDD	165	108	142	34.6	61.8	125	116	84.4	53.6	119	89.1			1,800		160
Total HxCDF	6.7	13.2	21.6	15	39.5	82.1	136	64	19.2	43.5	122			3,690		177
Total HpCDD	529	449	577	310	357	1080	788	959	187	531	356		24.6	25,060		828
Total HpCDF	25.8	39.9	56.1	45.5	76.6	241	248	170	22.7	78.7	439			8,780		332
OCDD	3460	3550	5070	3900	3830	5920	4820	4240	1040	3750	3450	58	336	81,930	4900	5180
OCDF	63.2	205	442	88.4	272	284	477	181	111	742	525		5.4	7,410	9840	6210
Toxicity Equivalence Calculations[c], TEQ_0	9.91	18.9	20.5	15.8	62.7	60.8	130	12.5	16.1	46.1	27.2	0.57	0.43	409	158	58.6
Toxicity Equivalence Calculations[c,d], $TEQ_{1/2}$	10.56	19.6	21.4	17.1	62.7	61.3	130	13	16.9	46.6	27.7	2.19	2.405	409	158	58.8

[a] Summer low-flow sampling episode (August 1993)

[b] Special sampling (May 1994)

[c] Calculations using 1989 toxicity equivalence factors (TEFs) with non-detected results set to zero.

[d] Calculations using one-half the detection limit.

Table 7. Dioxin concentrations in sediment from high-resolution sampling summer 2005

Station	TOC (%)	Total TEQ	Average TEQ	Total TEQ in OC	Average TEQ in OC
1	1.56	78.76		5,048	
2	1.37	64.51		4,708	
3	1.24	27.65		2,230	
4	0.56	12.21	13.71	2,172	2,281
4 (duplicate)	0.64	15.21		2,390	
5	0.72	10.41		1,445	
6	0.55	10.80		1,957	
7	0.65	14.03		2,174	
8	0.88	29.47		3,333	
9	1.19	11.61		976	
10	0.96	155		16,224	
11	0.83	525	550.75	63,353	66,147
11 (duplicate	0.84	575		68,942	
15	10.70	31,123	32,752	290,873	310,731
15 (duplicate)	10.40	34,381		330,589	
17	0.83	30.68		3,687	
18	1.02	35.96		3,525	
19	0.48	18.91		3,940	
20	0.15	1.81		1,206	
21	1.54	40.00		2,597	

Source: Rifai (2006a, Table 3-4, summer 2005 sampling event)

Notes: OC - total organic carbon
TEQ - toxic equivalent
Total TEQ in OC - also termed TOC-normalized concentration

Exhibit A

Curriculum Vitae of
Mark W. Johns, Ph.D., P.G., L.G.

Exponent
15375 SE 30th Place
Suite 250
Bellevue, WA 98007

telephone 425-519-8700
facsimile 425-519-8799
www.exponent.com

Mark W. Johns, Ph.D., P.G., L.G.
Principal Scientist

Professional Profile

Dr. Mark W. Johns is a Principal Scientist in Exponent's Environmental and Earth Sciences practice. Dr. Johns specializes in the evaluation of transport and fate of environmental pollutants, remediation, and cost allocation and apportionment. He has been the principal investigator on numerous remedial investigations and feasibility studies and has an extensive background in site remediation and cleanup. Dr. Johns has over 24 years of experience in the fields of geology, groundwater, and geological oceanography. He has been responsible for the technical direction of several large CERCLA-, TSCA-, and RCRA-related environmental studies pertaining to heavy metals, dioxins, PCBs, hydrocarbons, and chlorinated solvents. These studies have involved mine sites, petrochemical facilities, refineries, pipelines, and manufacturing sites throughout the U.S., South America, Australia, Europe, and the Middle East.

Dr. Johns has assisted clients with evaluations of remedial approaches and costs, and the influence of various site conditions. He has developed and applied innovative cost analysis tools using Monte Carlo uncertainty simulations to evaluate a range of probabilities and sensitivities involved in decision analysis, risk, and business planning purposes (i.e., litigation and insurance coverage).

Dr. Johns serves as an expert witness in environmental transport and fate and has provided expert testimony, reports, and declarations on the origin, fate, and transport of pollutants and the appropriateness of remedial cleanup and associated costs in soils, sediments, surface water, and groundwater. He has also provided expert assistance in evaluating compliance with the National Contingency Plan (NCP) and the allocation and appropriateness of remediation costs at a variety of sites.

Academic Credentials and Professional Honors

Ph.D., Geological Oceanography, Texas A&M University, 1985
B.S., Geological Oceanography, University of Washington, 1977

Licenses and Certifications

Licensed Geologist/Hydrogeologist, Washington, LG-1262 (2002)
Registered Professional Geologist, Wyoming, PG-3237 (1999)
Licensed Professional Geoscientist, Texas, License No. 3221 (2003)

40-Hour Hazardous Waste Operations and Emergency Response – Level A, HAZWOPER, 1986; 8-Hour HAZWOPER Managers and Supervisor Training; Advanced Health and Safety for Hazardous Waste Site Management, 1987; 8-Hour OSHA Annual Refresher; Registered Washington State Department of Ecology Underground Storage Tank Program, 1990

Division of Environmental Geosciences Charter Member (304092), 1993–present
American Association of Petroleum Geologists (AAPG, 304092), 1981–present

Publications

Krishnan PK, Freeman B, Johns M. Development of a risk based corrective action program for Kuwait environmental remediation project. Paper presented at the Kuwait Waste Management Conference and Exhibition, Kuwait, April 7–9, 2008.

Mackay CE, Johns M, Salatas JH, Bessinger B, Perri M. Stochastic probability modeling to predict the environmental stability of nanoparticles in aqueous suspension. Integrated Environmental Assessment and Management 2006 Jul 2(3):293–298.

Johns MW, Hickey G, Rice JA. Native revegetation of the middle section of the Provo River, Utah, 1999–2004—A work in progress. Proceedings Society for Ecological Restoration, 16th Annual Conference, Victoria, British Columbia, Canada, August 24–26, 2004.

Johns MW. Geotechnical properties of Mississippi River Delta sediments utilizing in-situ pressure sampling techniques. Handbook of Geophysical Exploration at Sea, Second Edition: Hydrocarbons, pp. 351–401, 1992.

Dunn DA, Biart BNM, Johns MW. Physical properties data, deep sea drilling project leg 93, sites 603, 604, and 605. Initial reports of the deep sea drilling project. Appendix I, XCIII(1). U.S. General Printing Office, 1987.

Johns MW. Consolidation and permeability characteristics of sediments from Deep Sea Driling Project Leg 93, Sites 603 and 604. Initial reports of the deep sea drilling project, Vol. XCIII. U.S. General Printing Office, 1987.

Prior DB, Bornhold BD, Johns MW. Active sand transport along a fjord bottom channel, Bute Inlet, British Columbia. Journal of Geology 1986; 14:581–584.

The Geotechnical Consortium, (member). Geotechnical properties of Northwest Pacific pelagic clays; deep sea drilling project, Hole 576A. Initial Reports of the Deep Sea Drilling Project, 1986.

Johns MW. Consolidation and permeability characteristics of Japan Trench and Nankai Trough sediments from DSDP leg 87, sites 582, 583, and 584. Initial reports of the deep sea drilling project, Vol. LXXXVII. U.S. General Printing Office, 1985.

Johns MW. Geotechnical properties of Mississippi River Delta sediments utilizing in-situ pressure sampling techniques, Ph.D. Dissertation, Texas A&M University, College Station, TX, 1985. 102 pp.

Johns MW, Prior DB, Bornhold BD, Coleman JM, Bryant WR. Geo-technical aspects of a submarine slope failure, Kitimat, British Columbia. Geotechnology 1985; 6(3):243–279.

Johns MW, Bryant WR, Dunlap WA. Geotechnical properties of Mississippi River Delta sediments utilizing in-situ pressure sampling techniques. Final Report by Texas A&M University, submitted to Minerals Management Service, Metairie, LA. Contract No. 14-08-0001-G-709, 1985. 101 pp.

Leg 93 Scientific Party, Member. DSDP Site 603: First deep (1000-m) penetration of the continental rise along the passive margin of eastern North America. Journal of Geology 1985; (13):392–396.

Van Hinte JE, Wise SW, Biart BNM, Covington JM, Dunn DA, Haggerty JA, Johns MW, Meyers PA, Moullade MR, Muza JP, Ogg JG, Okamura M, Sarti M, von Rad U. Deep-sea drilling on the upper continental rise off New Jersey, DSDP Sites 604 and 605. Geology 1985 June; 13:397–400.

Leg 93 Scientific Party, Member. Kretazisch-kanozoische stratigraphie und paleoenvironment-entwicklung am kontinentalfub vor dem ostlichen Nordamerika. Journal of Geology 1985; A75:237–259.

Prior DB, Bornhold BD, Johns MW. Depositional characteristics of a submarine debris flow. Journal of Geology 1984; (92):707–727.

Johns MW, Taylor E, Bryant WR. Geotechnical sampling and testing of gas-charged marine sediments at in-situ pressures. Geo-Marine Letters 1983; 2(3–4):231–236.

Presentations

Johns M, Edwards, M, Atlas, R, Duncan, B, Harney, J, Thompson, T. Evaluation of relationships among fluorescence, dissolved oxygen, and analytical chemistry measurements of the water column as indicators of MC252 oil in the Gulf of Mexico. Poster presented at the Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, November 13–17, 2011.

Johns M, Beckmann D. Subsea monitoring and analytical results: Subsea dispersed oil, MC252 Deepwater Horizon release. Poster presented at the International Oil Spill Conference (IOSC) for Oil Fate and Transport, Measurements and Modelling Section, Portland, OR, May 23−26, 2011.

Johns M, Edwards M, Atlas R, Harney J, Thompson T. Weathering of MC252 Oil in the water column of the Gulf of Mexico from May through September 2010: Fluorometry, dissolved oxygen, and quantitative chemistry evaluation. Poster presented at the Society of Environmental Toxicology and Chemistry (SETAC) North America Gulf Oil Spill Focus Topic Meeting, Pensacola Beach, FL, April 26−28, 2011.

Johns M, Beckmann D. Deepwater dispersant use and evaluation of subsea monitoring and analytical laboratory results for the MC252 Spill. Poster presented at the Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, Portland, OR, November 10, 2010.

O'Reilly K, Boehm P, Johns M. Technical approaches for apportioning liability and allocating environmental costs. Exponent Webinar, December 10, 2008.

Mackay C, Johns M, Salatas J, Bessinger B. Stochastic probability modeling to predict the environmental stability of nanoparticles in aqueous suspension. Society of Environmental Toxicology and Chemistry, 2005 poster session. Abstract reference No. MAC-1117-829575.

Johns M. Transport Chicago: Case study, Port of Chicago (3-part series). Invited presentation to Brownfield Redevelopment Environmental Issues; Making Democracy Work Speakers' Series, League of Women Voters of Chicago, 2003. (Also presented on CAN TV, Chicago.)

Johns MW. Potential environmental conditions associated with submerged floating tunnels. American Underground Construction Association, 1st U.S. workshop on submerged floating tunnels. Invited presenter and chair for environmental issues, Seattle, WA, May 18–19, 2002.

Johns MW. Salmon in the Northwest. Conference completed and approved by Washington State Bar by the seminar Group, October 19 and 20, 2001.

Johns MW. Fate and transport of contaminants in groundwater. Invited Presenter for Subsurface Transport and Fate of Contaminants (GHYD-403) Seminar, for the Northwest Environmental Training Center, May 9–10, 2001.

Johns MW. South America—grappling with hazardous waste. Invited Speaker for the Going Global Track, South America-Grappling with Hazardous Waste, Project Permitting and Politics in South America, of the HazWaste World Superfund XVIII, Washington, D.C., December 2–4, 1997.

Johns MW, Bigham GN, Dole SE. Emerging trends in remedial investigation/feasibility studies. Presented at the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. Conference, February 23–26, 1987.

Johns MW. Dangerous and hazardous waste characteristics. Guest Speaker at the Industrial Hazardous Waste Management and Pollution Prevention Training Course, Buenos Aires, Argentina, July 15–18, 1996 (USETI Course No. 96-013).

Johns MW. Characteristics of dangerous and hazardous wastes. Invited Speaker for Dangerous/Hazardous Waste section of the University of Concepción International Conference on Solid, Urban, Hazardous, and Dangerous Waste, Concepción, Chile, April 18–19, 1996.

Johns MW. Workshop Developer, Moderator, and Invited Speaker for U.S. Army Corps of Engineers Soil Vapor Extraction (SVE) Workshop, Tacoma, WA, May 24–25, 1994.

Prior Experience

Principal, AMEC Earth and Environmental, Inc., 1999–2003
Independent Consultant, 1998–2000
General Manager Latin American Operations, Radian International LLC (formerly Dow Environmental Inc., Dow Environmental Overseas Management Corporation, DEOMCO), 1994–1998
Manager, Environmental Sciences, AWD Technologies, Inc and Dow Environmental Inc., 1993–1994
Principal Scientist, Seacor, 1992–1993
Program Manager, PTI Environmental Services, 1987–1992
Senior Geologist, Tetra Tech, 1985–1987
Independent Geological/Oceanographic Consultant, 1981–1985

Project Experience

Retained to provide an analysis of the timing and occurrence of how hazardous materials came to be located a property in Waianae, Hawaii. A property owner leased a 10 acre parcel, for farming purposes to a third party. Unbeknownst to the owner, the parcel was then sub-leased for disposal of hazardous materials by several additional parties. Contamination included used batteries, sandblast material, used autos, painting wastes, etc. Several burn pits were located on the property. The site became known to the EPA criminal investigation division and was subsequently cleaned up under an emergency removal.

Provided evaluation of contaminant distribution and sources for a formerly leased parcel of marina space. Owners claimed that contamination at the dockside facility was the sole responsibility of the lessee.

Prepared an expert report pertaining to the concentration and distribution of metals; the EPA remedy selection process and regulations; and the NPL listing resulting from chat and tailings distributions in the Old Lead Belt of St. Francois County Missouri. The Big River Mine Tailings site consists of seven separate mine chat and tailings piles. The chat and tailings deposits are waste materials produced by the extraction, beneficiation, and processing of minerals at this site. Chat deposits include sand- to gravel-sized material resulting from the crushing, grinding, and dry separation of the ore material. Tailings deposits include sand- and silt-sized material produced by the wet washing or flotation separation of the ore material.

Prepared expert report regarding the remedial actions and associated costs that were implemented at the Kings Plaza Shopping Center after July6, 2006, to address a discharge of No. 2 heating oil associated with the underground storage tank system located in the area referred to as Operable Unit 1. Kings Plaza Shopping Center is located at 5100 Kings Plaza, Brooklyn, New York.

Prepared a detailed work plan attachment and negotiated with the Washington State Department of Ecology for an Administrative Order for the conduct of an RI/FS for the Western Port Angeles Harbor. The work plan focused on filling data gaps for dioxins, PCBs, wood waste, metals, and sediment bioassays. Contamination resulted from decades of industrial activities, including paper production, sawmills, plywood mills, and associated forestry industries in the harbor area. Work includes providing QA/QC oversight, database management and a document repository for the RI/FS that is anticipated to be complete by the end of 2014.

Provided an expert opinion on a $250 million CERCLA cost recovery action against the United States based on government involvement at a Cold War-era rocket manufacturing facility in Southern California. Work included evaluation of NCP compliance and remedial actions.

Provided review and evaluation of cleanup action occurring at the PlusPetrol crude pipeline spill sites near Villa Trompeteros, Peru. Exponent verified the areal extent of environmental impacts in each zone via visual inspection; reviewed actual or planned remedial activities in the field; and recommended any additional or more appropriate, remedial measures than those observed in the field or planned according to available documentation. In addition, comments and recommendations were provided on the following: general technical approach and competence of response, remediation, and restoration actions; status of regulatory compliance with existing permits and regulatory guidance; proportionality of response in relation to scope of impacts; cost effectiveness of response in terms of efficiency relative to standard practice, preferred alternatives, or resources utilized; and projected timetable for response, including sequencing and duration of activities.

Estimated remediation costs for contingent environmental liability accrual purposes. Performed feasibility-level remediation cost estimate for a historic ash landfill on the site of an industrial facility. Estimated costs for various remediation options for the ash landfill associated with a paper production facility. Project involved preparing estimates of onsite ash volumes and costs using RACER software associated with removal and offsite disposal versus an in-place grade-and-cap plan.

Retained as the inter-creditor environmental agent during the construction period at the Cartagena Refinery (Rificar, S.A.) in Cartagena, Colombia. Responsible for evaluation and reporting of site environmental and social conditions during the $5.18 billion refinery and upgrade project reporting directly to the Ex-Im Bank and other international senior lenders. The expansion will increase the refinery capacity from 78,000 to 160,000 barrels per day.

Performed the environmental and social due diligence (ESDD) evaluation for the Cartagena Refinery (Rificar, S.A.) in Cartagena, Colombia. Prepared the ESDD report for Ex-Im bank and a group of international lenders to review and include in loan documentation.

Evaluated the proposed total maximum daily loads (TMDLs) for toxic pollutants in the Dominguez Channel and Greater Los Angeles and Long Beach Harbor waters Implementation

Plan. Provided comments to the California Regional Water Quality Control Board, Los Angeles, California, regarding environmental and dredging issues.

Performed environmental baseline and evaluation of environmentally sensitive areas for a major refinery upgrade at the Refineria ISLA Curacao B.V. located in Willemstad, Curacao. New project upgrades involved the development of processes and equipment to reduce atmospheric emissions and improve air quality at the 250,000 BOPD facility. Reviewed site documentation regarding environmental and social due diligence on behalf of the client in preparation for development of documentation for international lending institutions. Identified areas and analyzed mitigation options to protect the areas from any environmental and safety impacts that will be required for the environmental impact assessment (EIA) and the environmental monitoring plan of the project.

Provided expert analysis and report regarding potential historic remediation activities and associated costs for the PCS Nitrogen site in Charleston, South Carolina. Evaluated the probability that Ross Development Corporation (Ross) would have been liable for remedial actions at the site, whether remedial costs could have been reasonably estimated, and the costs of those remedial actions at the time Ross knew of its liability.

Performed international regulatory review and analysis for mine sites located throughout the world. Tasks included reviewing water quality drivers for various regulatory actions that are occurring. This included collecting and evaluating water quality regulations or standards that are applicable to inorganic constituents (i.e., arsenic, cadmium, copper, lead, zinc) in the western United States, parts of South America (Chile and Peru), Canada, Mexico, and Australia. These data were used to evaluate current mine site facility permit and/or general regulatory requirements for pre-treatment of mining wastewater prior to discharge and provide an overview of enforcement activities. An assessment of the regulatory climate, including types of requirements, frequency of evaluation, and enforcement actions was conducted.

Provided an evaluation of contaminant apportionment, transport, and fate from the Grand Chenier Gas Plant and Separation Stations located near Grand Chenier in Cameron Parish, Louisiana. The Grand Chenier Gas Plant operations provided on-shore facilities for the production and separation of liquids from the gas production facilities located offshore. The various facilities had elevated levels of NORM, metals, and TPH.

Retained as expert for the *Joseph A. Pakootas, et al. v. Teck Cominco Metals Ltd*. case to provide an evaluation of the divisibility of the harm arising from metals contamination at the Columbia River site and opine on whether reasonable scientific evidence was present to support that division and apportionment. Reviewed data for inorganic metals contributions to the Columbia River system including landslide, background, and anthropogenic sources.

Performed data analysis for the MC252 Deepwater Horizon oil spill. Analyses focused on water analyses in the deep water of the Gulf of Mexico. As part of the MC252 oil spill response action, BP initiated a program of adding dispersants at the well head. The Submerged Monitoring Unit was established to evaluate and track subsea dispersed oil using two vessels equipped with conductivity, temperature, and depth (CTD); dissolved oxygen; fluorometry; and deep water collection capabilities in addition to detailed quantitative chemistry. Field fluorometry measurements were used to track the location of the subsea dispersed oil in real time and water chemistry samples were collected and analyzed to quantify the field measurements.

Performed environmental and social due diligence and review for a major refinery upgrade at the Cartagena Refinery (Rificar, S.A.) in Cartagena, Colombia. Project upgrade involved development of a 165,000 BOPD facility to international standards. Reviewed site documentation regarding environmental and social due diligence on behalf of international lending institutions.

Retained as expert on behalf of the Official Committee of the Unsecured Creditors of ASARCO LLC Bankruptcy case in the US Bankruptcy Court for the Southern District of Texas, Corpus Christi Division. Prepared expert reports pertaining to multiple mining, milling, and refining sites located across the United States. Reviewed multiple cost assessments provided by the debtors, including NCP issues pertaining to the remediation at various sites and cost estimation methods following ASTM standards and using Monte Carlo analyses. Case included $6.5 billion in environmental claims for approximately 75 sites in 19 states (AL, AR, AZ, CA, CO, ID, IL, IN, KS, MO, MT, NE, NJ, NM, OH, OK, TX, UT, WA) and Canada for the integrated copper mining, smelting, and refining company.

Retained to provide expert review of remedial actions and contracting mechanism used for remediation of property adjacent to a railroad shop complex in Livingston, Montana. The plaintiffs were seeking monetary damages from the defendant for conditions resulting from site maintenance operations at the railroad shop complex. Site groundwater, surface water, and soil were contaminated with chlorinated solvents, hydrocarbons, metals, and asbestos.

Retained to perform a study to quantify emissions sources at Kuwait Oil Company (KOC) operations in the South Kuwait and West Kuwait fields and evaluate potential health risks from these emissions on Ali Sabah As Salem and Sabah Al-Ahmad Future City residential areas. The objective of the assessment was to determine whether there was a risk to residents in the existing city and future city from constituents in air emissions from the KOC South and West fields. The assessment was developed using air dispersion modeling results based on AERMOD modeling wherein estimates of the concentration of particulate matter (PM10), carbon monoxide (CO), carbon dioxide (CO2), methane (CH4), nitrogen dioxide (NO2), nitrogen oxides (NOx), non-methane hydrocarbons (NMHC), and sulfur dioxide (SO2) were compared to the corresponding ambient air standards or air quality guidelines in Kuwait (Environmental Requirements and Standards in the State of Kuwait, 1996) and the United States (U.S.) (National Ambient Air Quality Standards.

Compared the Kuwait Environment Public Authority's (KEPA) Regulatory chapters and appendices to similar United States (US) laws and their applicability to the petroleum and petrochemical industry of Kuwait. The purpose of the review was to provide process modifications to the industry that would result in improved environmental performance by the oil industry.

Retained to evaluate cost and liabilities associated with multiple petroleum facility remediations for sites located throughout the country.

Provided expert report to address issues concerning the investigation, remedy selection, and costs associated with a 3,000 gallon heating oil fuel spill on the Western Asphalt property in Jacksonville, Illinois.

Provided expert ligation support to addresses fate and transport of contaminants, remedy selections, and cost allocation at the Intalco Aluminum Smelter Site, Ferndale, Washington. Site consisted of an aluminum processing facility with several landfills and dumps that contained process wastes including spent potliner, anodes, brick, and other process wastes. Contaminants included cyanide, PCBs, and metals.

Provided litigation support with the evaluation of facilities that produced 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (agent orange). The evaluation included review of sediment contamination of sediments in an estuarine system.

Provided expert ligation support to addresses remedy selections, cost allocation, and contributions at the Hard Chrome Products site. The Hard Chrome site was located adjacent to a former aircraft parts manufacturing facility that was purchased by the Los Angeles Unified School District (LAUSD). Groundwater and surface soil was contaminated with chromium and tetrachloroethylene (TCE) plume(s) that resulted from use in the manufacturing process.

Prepared site evaluation strategy as it pertained to the other potential litigants in the Port Angeles Harbor watershed and the Puget Sound Initiative evaluation of the Port Angeles Harbor. The evaluation focused on dioxins, PCBs, wood waste, and metals contamination resulting from decades of industrial activities, including paper production, sawmills, plywood mills, and associated forestry industries in the harbor area. Prepared sampling and analysis plan for evaluation of sediments in the Port Angeles Harbor for dioxin, PCBs, metals, and other contaminants. Work included collection and analysis of both surface grab and core samples.

Provided consulting assistance with fate and transport analysis of crude oil spills in the Amazonia region of eastern Ecuador.

Provided expert opinion on the cost of remediation and allocation to parties resulting from the deposition of mine spoils and waste at the Magnet Cove barite mine in Magnet Cove, Arkansas. Former underground and open-pit spoils and waste rock were placed adjacent to the mine. Subsequent to mine closure in 1977, the pit lake filled with acidic water that required treatment.

Developed conceptual site model for remediation of dioxin-contaminated sediments in the eastern swale area of a former plywood mill located in Eureka, California. In 2006, Humboldt Bay was added to the U.S. Environmental Protection Agency’s nationwide list of impaired waterways during the State Water Board meeting. Prepared remedial action plan and mediation documentation in anticipation of litigation.

Provided oversight in the preparation of a cleanup action plan (CAP) to address lead contamination at a site in Pauma Valley, California, in accordance with the County of San Diego Department of Environmental Health (DEH) 2003 Site Assessment and Mitigation

(SAM) Manual. The Site was unknowingly affected by lead during and after polypropylene recycling activities that took place on the site during 1979–1980.

Assisted with the evaluation of arsenic-rich sediments contained in the buried Bingham Magna Ditch, Utah. Historical use of the ditch resulted in enrichment of the sediments with arsenic and other metals. Subsequently, the ditch was buried, and construction of homes and businesses occurred in the vicinity of the ditch.

Provided litigation support with the evaluation of facilities that produced 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) (Agent Orange). The evaluation included review of by-product production and loss of dioxin from the production plants.

Provided expert testimony regarding proposed remedial actions, cost allocation, and transport and fate analysis, with source identification of PCBs, hydrocarbons, dioxin, and heavy metal contamination from the Central Waterfront Landfill, located on Bellingham Bay, Washington. Work included evaluation of groundwater, geology, and geologic oceanography.

Provided expert testimony at deposition and trial regarding cost allocation and apportionment; transport and fate of gasoline, diesel, and lead; remedial system performance; and groundwater flow characterization for the Ferrysburg, Michigan, storage and distribution terminal. The site consisted of 27 acres on which a bulk storage terminal (capacity 13.5 million gallons) and transfer facility were located. Truck loading activities resulted in plumes of nonaqueous-phase liquid (NAPL) and dissolved product that required remediation. This was accomplished by installing a pump-and-treat system with a skimmer. Property ownership changed hands, and new spills resulted in a commingled plume.

Reviewed the remedial investigation and prepared comments for the Rayonier Mill site in Port Angeles, Washington. The site is located on the shore of Port Angeles Harbor, on the Strait of Juan de Fuca, and was operated between 1930 and 1997 using the acid sulfite process to produce dissolving-grade pulps from wood chips.

Provided litigation support for the evaluation of potential remedial and primary restoration costs for the Grand Calumet River and Indiana Harbor and Canal along Lake Michigan. The area is affected by several industrial activities, including steel mills, oil refineries, wastewater treatment plants, petrochemical plants, and others. The remedial cost analysis included evaluation of dredging, capping, and natural recovery. Also included was the analysis of primary restoration costs associated with the non-remediated areas of the site.

Provided expert declaration and was retained to provide expert testimony regarding NCP compliance for the long-standing McColl Superfund Site remediation project in Fullerton, California. The State and federal government were seeking cost recovery in excess of $40 million. Site contamination consisted of approximately 73,000 cubic yards of acid sludges and tars that had been placed in pits and ponds on the site in the 1940s. Remedial measures were implemented in several phases, such as waste incineration, thermal treatment, in-situ solidification, and capping.

Serving as project manager for refinery storage tank failures as a result of Hurricane Katrina at two facilities in Buras and Port Fourchon, Louisiana. Preparing an assessment of the oil spill, the nature, and extent of resulting contamination, and its effects on ecological receptors. Work includes an evaluation of the storm surge and root cause of material failures.

Provided expert declaration regarding groundwater and surface water controls for the Bunker Hill Mine in Kellogg, Idaho. EPA prepared a Record of Decision (1992) for a non-populated area of the site that included treatment and removal controls and associated costs for solid wastes, surface water, and groundwater. This included area mine-water treatment by collection and treatment of waters that infiltrated from above the Kellogg Tunnel level, as well as the deeper mine water that was required to be maintained at the level of the Coeur d'Alene River. The various sources of mine water had considerably different quantities and concentrations of heavy metals. The sources of the water were evaluated, and an expert report was prepared that presented the load distributions and estimated treatment costs for each source.

Provided senior direction for the application of a multidisciplinary ecological risk assessment of the effects of fugitive dust from the Red Dog Mine, haul road, and port in evaluating potential mine closure scenarios. The risk assessment modules included evaluating the effects of potential metals concentrations on sensitive tundra habitats and subsistence foods. The 29-square-mile permitted mine area was divided into zones in which different closure scenarios could be applied; then ecological risks were evaluated by area.

Provided senior oversight for the evaluation of sources of arsenic, cadmium, lead, and zinc in the vicinity of a historical zinc smelter.

Provided senior direction for development of a framework to assess arsenic and lead concentrations throughout a residential community. Arsenic and lead associated with the site resulted from mining and mill tailings from historical copper mining and smelting. Residential concentrations were compared to national cleanup criteria developed for various national sites.

Retained to provide expert testimony regarding probable remedial activities and associated costs for PCB-contaminated sediments in Convair Lagoon, San Diego, California. Evaluated source control and recontamination of an existing cap for the 7-acre site. Potential remedial actions included complete removal to thin-layer capping with monitored natural recovery, after implementation of source-control measures.

Provided opinions and litigation support for the evaluation of a 40,000-gallon diesel fuel spill into a containment system that failed. The failure resulted in the net loss of approximately 30,000 gallons of fuel to the soil beneath the containment structure. Provided cost estimates for probable cleanup scenarios.

Retained to provide expert testimony regarding cost apportionment for costs resulting from remedial action activities in the Everett Harbor, Washington. The evaluation included review of site RI/FS documentation, remedial action activities, construction, dredging, transport-and-fate analysis, and post-action monitoring. Contaminants of concern include PCBs, PAHs, metals, and hydrocarbons and deleterious waste.

Retained to provide expert testimony regarding cost apportionment for all costs resulting from remedial activities in the Thea Foss Waterway, Tacoma, Washington. The evaluation includes review of site RI/FS documentation, remedial action activities, construction, dredging, transport-and-fate analysis, and post-action monitoring. Contaminants of concern are PCBs, PAHs, metals, and hydrocarbons.

Served as an invited advisory board member and expert for the California Childhood Lead Poisoning Prevention Program (CLPP) evaluation of sources, fate, and transport of lead in the environment in California. The California Department of Health Services (CDHS) established a fee allocation to fund the program in 1991, based primarily on the amount of lead consumed by the gasoline and architectural coating industries in California between 1929 and 1986. The California Supreme Court ruled in 1997 that the fee would not be considered a tax, so long as the basis for apportioning the fee bore a reasonable relationship to the fee payer's contribution to the burden addressed by CDHS's CLPP program. Was a member of the expert team that conducted an independent analysis for a major petroleum company of the appropriateness of the current fee allocation. This team reviewed source, fate-and-transport, epidemiology, and toxicology reports for California cases. Trial was held in California Superior Court in December 2007.

Retained to develop remediation cost projections for two large remediation projects related to the Raybestos facility in Crawfordsville, Indiana, and to present and defend those estimates at trial. The project also included allocation of prior Exponent costs related to offsite remediation. Developed a probabilistic cost estimate for application to past and future site remediation costs. The Superior Court for the State of Indiana ruled (October 30, 2006), awarding Raybestos 100% of the cost estimates and allocation, accepting the cost methodology and approach, and recognizing the expertise in these matters.

Prepared a focused feasibility study for the remediation of Reach 4 of the Shelly Ditch in Crawfordsville, Indiana. The site consists of PCB-contaminated sediments and floodplain deposits along a small stream emanating from a former brake manufacturing plant. The evaluation considered human health and ecological risk to develop practical options. The preferred alternative included evaluation of hot-spot removal, with monitored natural recovery in inaccessible areas. Provided remedial scenario development and most probable cost analysis for the client. Designated as the Site Manager in the Administrative Order on Consent (AOC) and oversaw the successful remediation of the floodplain sediments and closure of the site in 2008. The project was completed on budget and schedule.

Provided litigation support to outside counsel to review and assess the emergency response to an event at the Plutonium Reclamation Facility and to review and assess the emergency response plan for the Plutonium Finishing Plant (which included the Plutonium Reclamation Facility) at the Hanford Nuclear Site, being operated under contract from the Department of Energy. Specifically, the assignment included a critique of the emergency response to the incident and the applicable portions of the emergency response plan with regard to whether the response was timely, appropriate, and protective. Additionally, the assignment included an assessment of the plan and response with regard to improvements that could be made during future Emergency Responses.

Estimated the probability of costs for each of six different remedial alternatives using Monte Carlo methods in cost allocation negotiations among PRPs of a site with PCB sediment contamination at Upriver Dam in Spokane, Washington. Remedial alternatives included monitored natural attenuation, capping, and dredging options. In the Monte Carlo approach, a probability distribution that describes the uncertainty of values, rather than a single best-guess value, was considered for each cost element in the remedial option. Evaluated individual remedial alternatives for probability of occurrence, and calculated a weighted mean value for different scenarios bounded by 90th percentile upper limits as compared to an expected-mean-value (50th percentile) calculation.

Provided an expert declaration to help understand an “incentivized” contracting mechanism used for remediation of property adjacent to a railroad shop complex in Montana. The plaintiffs were seeking monetary damages from the defendant for conditions resulting from site maintenance operations at the railroad shop complex. Site groundwater, surface water, and soil were contaminated as a result of the Livingston Railyard and the surrounding area, where hazardous or deleterious substances have been deposited, stored, disposed, or otherwise come to be located.

Managed the team that evaluated dense, nonaqueous-phase liquid (DNAPL) transport from the Manufactured Gas and Coking site to the Island End River (Massachusetts) sediments. This included a forensic analysis of the PAH source and deposition areas. PAHs were evaluated successfully using cluster analysis. Remedial cost apportionment was applied using the results of the PAH analysis.

Performed a site due diligence evaluation and cost analysis for the construction of a hotel and spa in the Deer Valley Ski Resort (Utah) on the site of a former mine waste-rock pile that contained heavy metals. Work included evaluation of potential human and ecological impacts resulting from construction activities on the waste rock.

Managed the team that provided expert analysis of the most likely probable risk scenario for a contaminated barrel-reconditioning site. This information was used to develop a cost cap insurance policy for the site. A site-specific air dispersion model was developed for three scenarios: normal surface conditions, furnace operations, and an upset condition. Resultant hazardous air pollutants were modeled, and a human health risk calculation was applied. The site operations included barrel reconditioning by furnace treatment, followed by sand blasting, then interior and exterior painting with heat treating. Over a period of years, neighbors filed numerous complaints about poor air quality resulting from the operations. During an upset condition, the downwind neighborhood was subjected to a noxious plume. This resulted in the filing of a lawsuit by more than 500 plaintiffs.

Provided litigation support to a large metals recycling company regarding remediation of certain areas of uplands and sediment in the East Waterway of the Duwamish River in Seattle, Washington. Evaluated fate and transport of chemicals of concern (PCBs, metals, PAHs) from the uplands site to the waterway at Harbor Island, as well as the proposed dredging. Reviewed cost allocation and environmental issues relating to the company’s possible link to a PCB hot spot.

Reviewed existing site investigation and remediation documentation as part of litigation support in a case involving a former metals fabrication facility site on the Duwamish River in Seattle, Washington. The site had been purchased and was being redeveloped by a large metals recycling company. Prepared GIS-based, time-sequential contaminant mapping and evaluated the extent of preexisting contamination, then combined that information with a cost analysis review. Contaminants included inorganic compounds, chlorinated solvents, and petroleum products. Site evaluation included all upland source areas, former dredge fill sites, an underground petroleum pipeline, and former rail lines.

Provided litigation support to a marine ship dismantling company that formerly operated on the Hylebos Waterway in Tacoma, Washington, a part of the Commencement Bay Nearshore/ Tideflats Superfund Site. This work included a cost evaluation of natural resource damages, potential restoration options, and remedial actions. Contaminants included hydrocarbons, PCBs, metals, PAHs, and deleterious wastes. Cost apportionment was evaluated with respect to contaminants present in the sediments.

Retained by the Kasper (1977) Irrevocable Trust to provide expert analysis and litigation support regarding costs associated with the development of a remedial investigation/feasibility study (RI/FS) at the American Drive-In Cleaners site in Levittown, New York. NYSDEC had taken more than 13 years to develop the RI/FS and final Record of Decision for the site. In addition, excessive costs associated with oversight and management of the site by NYSDEC and EPA had accrued, and the remedial selection process had resulted in a solution for which costs would exceed $5 million.

Directed the development of a sampling and analysis program for evaluation of the sediments along canals and waterways associated with a major refinery in Argentina, where a high degree of hydrocarbon contamination in the water at a nearby yacht club was resulting in a bloom of *Microsystis aeruginosa* (cyanobacteria, with hepatoxins). The plan included the evaluation of Ce-137 and Pb-210 radio-dating techniques, combined with geochemical fingerprinting, to apportion the site remediation/restoration responsibilities.

Retained to provide expert opinion in support of the Port of Bellingham's case against its insurers. Issues included the ownership, presence, fate, and transport of contaminants from four separate sites located along the waterfront of Bellingham Bay in Bellingham, Washington. The sites consisted of former landfills, wood-treating facilities, and sawmills. Reviewed extensive technical reports and cost analyses for data compiled for each site. Findings and opinions were presented in an expert declaration that reviewed the fate and transport of metals, PCBs, PAHs, and dioxins.

Project manager for the development and installation of an ArcIMS system for the Port of Seattle. The system was designed to provide quasi-real-time facilities information for all buildings and levels during reconstruction of the airport. The system also provided environmental data views for development of the Third Runway.

Retained by Gordon and Polscer, LLP to provide litigation support pertaining to the Summitville Mine Superfund Site in Rio Grande County, Colorado. The site is a former gold and copper mine that operated since the 1870s and was added to the EPA NPL in 1994. Reported findings and opinions on general description of various contaminants, conditions, and operable units being investigated or remediated; the nature of the costs expended on each investigation and/or remediation; and the segregation of project costs between those generally deemed to be a cost of doing business in the mining industry and those that can be attributed to unanticipated remediation costs.

Served as Project Manager for the investigation and removal of approximately 30,000 yd^3 of potentially contaminated soil and asphalt material at the Terminal 18 site on Harbor Island, Washington. Designed and prepared a sampling and analysis plan (SAP) in an expedited fashion (less than 1 week). A volume of approximately 25,000 yd^3 of asphalt material was designated for recycling, resulting in a significant cost savings. Approximately, 5,000 yd^3 of soil required disposal at a non-hazardous landfill, and only 150 yd^3 required disposal at a designated hazardous landfill. All material was removed from the site prior to the redevelopment deadline, thus avoiding significant fines and costs associated with disposal at a hazardous waste landfill.

Performed a site assessment and evaluation of historical upland and sediment disposal practices along the Tacoma waterfront for a confidential client. The work focused on evaluating pyrogenic versus petrogenic PAHs and included evaluation of coal and refined petroleum hydrocarbon distribution across the site. Cost analysis included review of solid waste disposal costs.

Developed and implemented a sampling and analysis plan for the Sandy Hook (New Jersey) Maintenance Dredge and Beach Nourishment Project. The objectives of the project were to restore adequate depth in a privately maintained navigation channel leading to the Sandy Hook Yacht Club Estates Marina, restore and stabilize the Sandy Hook beach, and provide the potential for surf smelt and sand lance habitat. The maintenance dredging permit was obtained from the U.S. Army Corps of Engineers. The channel sediments were sampled and analyzed and found suitable for dredging and placement onto the Sandy Hook beach as a habitat enhancement project.

Provided expert declaration and expert testimony for the case of Morrison Knudsen Citation and Notice No. 30304540, No. 01 W0158 with the State of Washington Board of Industrial Insurance Appeals. Reviewed extensive data sets for metals concentrations and distributions in site soil and worker personal air monitoring equipment. Applied a Roesner's sequential procedure for determination of probable outliers with a successful outcome.

Prepared an expert report and provided expert testimony for potential wetland impact from vehicle emissions and stormwater runoff at the Aegis Assisted Living site in Shoreline, Washington. Neighbors challenged the original delineation studies, and subsequent SEPA evaluations during construction activities (File No. 2000-0821). The court was unable to find any analysis of consequential impacts of vehicles using the services—for example, potential adverse impacts of auto traffic, exhaust, oil spillage, and contamination—within the 1-ft buffer of the stream (Thornton Creek) and the 50-ft buffer of the wetlands. Retained to provide expert opinion on the relative impacts to the wetland environment.

Served as project manager for the Brownfield redevelopment of a 50-acre former construction debris landfill parcel on the north end of Lake Washington (Seattle area). Contaminants included asbestos-containing materials, arsenic, and petroleum hydrocarbons in soils and groundwater located throughout the site. Regulatory guidelines were developed for all media, based on the most appropriate site data as applied to both human and ecological receptors. Designed the program timelines to meet the permitting and SEPA environmental deadlines for a very compressed schedule prior to the initiation of the new MTCA regulations. Redevelopment values are estimated to be $200 million for the phased development of condominiums, restaurants, and businesses throughout the site.

Served as program manager for the development of corporate-wide risk management and emergency response planning studies for a major software company. Performed a post-mortem analysis of the Nisqually earthquake and 9/11, using a cross-group emergency management team that included Security, Real Estate and Facilities, Internet Technology Group, Risk Management, Human Resources, Public Relations, and Legal & Corporate Affairs. This team worked together to develop the corporate-wide Puget Sound emergency response plan (ERP). The plan evaluated potential natural and man-caused disasters from the individual, building, and corporate-wide viewpoints. It included implementation at 75 building locations, affecting 40,000 employees. The efforts complemented other measures that corporate security was implementing to increase the safety and security of the Puget Sound locations. This project was highly successful and was supported by management. The work included development of building-specific ERPs, online training tools, quick reference documents for each office, building signage, drills, and cross-organizational ERPs.
Retained by Bankston & McCollum to provide oversight for the investigation and sampling activities, potential remedial costs, and litigation support at the North 60° Petro site in Whitehorse, Yukon Territory. Prepared a comprehensive report detailing contaminant distributions throughout the site. The site was used as part of the Canol Project, which included a large oil refinery built as part of the World War II defense strategy by the U.S. Army Corps of Engineers. The project also involved the development of the Norman Wells oilfields and construction of several sections of crude-oil pipeline to the refinery in 1944.

Served as project manager for the Haug Channel Homeowners Association step-wise sediment evaluation prior to initiation of potential dredging activities at this shore-side community at the southern end of Fairweather Bay in Hunts Point, Washington. Performed an evaluation of existing sediment conditions (surficial and at depth), comparing the results to local use standards, sediment management standards (SMSs), and Puget Sound Dredged Disposal Analysis (PSDDA) protocols in anticipation of dredging activities. Prepared the SAP and quality assurance project plan (QAPP), performed the sampling, and generated the final report.

Managed the drilling, water sampling, pump testing, and modeling of aquifer characteristics for two wells at the Cama Beach and Lime Kiln Point State Parks. Lime Kiln Point State Park is located on San Juan Island, where existing wells had exhibited saltwater intrusion. A new 5-in. water well was installed to 560 ft in difficult basalt geology. Cama Beach State Park is located on Camano Island, Washington, and required a new 6-in. well. Sampled both wells to determine requirements for potable water. Twenty-four-hour pump tests were used to determine aquifer characteristics.

Served as project manager and evaluated existing sediment conditions (surficial and at depth), comparing the results to SMS and PSDDA protocols in anticipation of constructing a reinforced concrete haulout for Delta Marine Industries, Inc. Prepared the SAP and QAPP, performed the sampling, and generated the final report. Following successful negotiation of a joint aquatic resources permit application (JARPA) with the U.S. Army Corps of Engineers and the Washington State Department of Ecology (Ecology), the Delta Marine boatlift, as planned, was constructed in 2000. Ecology's response letter reported a No Further Action decision and commended the high quality of the report.

Managed geological evaluation for an *in situ* vitrification project at Los Alamos National Laboratory Radiological Waste. A drain field that was constructed to dispose wash water from laundry facilities at the laboratory was contaminated with particles of low-level radiation. *In-situ* vitrification was conducted, as a field scale pilot study, using a small scaled test module to determine how to reduce radiological contamination of the contaminated soil water contained within the drain/septic field.

Managed an evaluation of near-surface sediments in the vicinity of Totem Marina, a pleasure boat and yacht marina (Commencement Bay, Washington) with haul-out facilities, upland dry storage, and marine sales and service, on behalf of a potential purchaser. Prepared the SAP and QAPP, performed the sampling, and generated the final report.

Served as project manager for a criminal investigation directed by EPA Region 10 as a result of the removal from a CERCLA site of 660 yd^3 of potentially contaminated soil. The soil was disposed at a commercial topsoil facility near Maple Valley, Washington. Because these soils were not sampled prior to removal from the CERCLA site, and were placed at an offsite facility without proper manifesting, the Criminal Investigation Divisions of EPA and Ecology monitored all site investigation activities conducted at the offsite facility. Detailed sampling and analysis resulted in location of the suspected soil and determination that it was below regulatory levels. This case resulted in no criminal actions.

Served as principal investigator providing expert guidance for the evaluation of the former Matsushita Semi-Conductor of America Facility in Puyallup, Washington, prior to transfer of the property to Microchip Corporation ($80 million). The environmental site assessment included collection of sediment, soil, sludge, groundwater, and surface water samples throughout the 686,000-ft^2 cleanroom facility and 92-acre campus. The plant consisted of three main building areas equipped with state-of-the-art clean rooms and air emission and wastewater treatment facilities, and was surrounded by parking and delivery drives.

Participated in the Calcasieu Estuary Study as a project manager. The study area consisted of the surface water, sediments, and related wetlands and wetland soil of Bayou d'Inde, Bayou Verdine, the Calcasieu River, and the Calcasieu Ship Channel from the saltwater barrier to the northern end of Moss Lake near Lake Charles, Louisiana. Led the team in developing an integrated RI/FS and NRDA work plan and submitted it to EPA, the Louisiana Department of Environmental Quality, NOAA, and the U.S. Fish and Wildlife Service for review and comment. The statement of work represented one of the only cases in which the RI/FS and NRDA processes have been fully integrated. The work plans detailed the processes used to develop all field sampling protocols and integrate the evaluation of remedial and restoration alternatives for chlorinated solvents, dioxins, PCBs, PAHs.

Served as the site operations manager for the United Park City Mines Company. Developed and implemented site restoration and revegetation plans for several high mountain (5,500 to 9,000 ft amsl) mine sites. The sites included waste-rock dumps, milling, processing, and hard-rock shaft locations. The sites varied dramatically in slope, aspect, elevation, erosion potential, topsoil, water retention capacity, etc. These areas were redeveloped as home sites.

Served as manager of site operations and implemented restoration and revegetation activities to return native species to a man-made, highly disturbed lake structure. This restoration work involved combining different aspects of environmental and landscape design to produce a natural habitat with native plants and sufficient fish habitat for a viable system. The effort included several innovative techniques to ensure that restoration activities resulted in a viable system and minimized additional disturbance. All landscape, native plantings, fish habitat, stream modification, and final contouring on the lake were performed prior to filling. Construction work included surveying, soil removal and placement, large structure and rock placement, dam spillway placement, erosion control measures (vegetative and geotextile), entrant stream modification, aeration (natural and solar powered), dock installation, irrigation (pressure-head driven, non-invasive), and native plantings (trees, shrubs, grasses, wildflowers, and forbs).

Technical reviewer and site expert for the evaluation of chlor-alkali plant operations and contaminant distributions in the site soil and groundwater around the Buna Petrochemical Refinery in Buna, Germany. Provided input into development of sampling programs and protocols for soil, groundwater, and sediments. Contaminants included chlorinated solvents, TCDD, vinyl chloride, and mercury. Reviewed and developed potential remedial scenarios and cost analysis.

Prepared the site uplands and sediment data collection and evaluation report in preparation for soil and sediment remediation at a former Union Carbide petrochemical plant at Homebush Bay, near Sydney, Australia. The site had produced Agent Orange (2,4-D and 2,4,5-T, dioxins) for use during the Vietnam War. Manufacturing processes and various spills had contaminated site-wide soil and nearshore sediments of the western bay shore. The report provided a basis for establishing cleanup goals with consideration of human health, ecological risk factors, and local regulations.

Provided technical input and oversight in the development of a sampling and analysis plan for the investigation of DNAPL contamination at a petrochemical facility in Altona, Victoria, Australia. The DNAPL wastes had been placed in landfills on the site and consisted of chlorinated solvents with PCBs and dioxins. The site geology consisted of clays and silts but was complicated by the presence of a fractured basalt aquifer in the subsurface.

Served as a program manager for an extensive site assessment and soil sampling program for evaluation and remediation of a 20-hectare former tank farm and refinery sludge storage area located at the Dock Sud industrial complex of Buenos Aires, Argentina. Heavy industry, including petroleum and chemical refining, paint pigment production, glass, coking, etc., used the immediate area surrounding the facility. The team performed a site investigation and remedial actions analysis to determine the necessary remediation system. Several remedial options were evaluated, including incineration, thermal desorption, *in situ* fixation, slurry wall and cap, groundwater treatment, landfill, and no action. In late 1996, the site remediation was initiated using in-situ fixation and soil stabilization. The team used multi-national and World National Health Organization analytical tools to develop remedial options and present the first judicially approved risk-based cleanup criteria for Argentina. Total estimated project value was $5,200,000.

Supervised the analysis of the plant wastewater source characterization of a chemical plant in Aratu, Brazil. All sources of water in the plant were evaluated to prepare a design and cost basis for the proposed plant wastewater treatment system upgrade. The work included preparation of all Phase I design package and project control materials. The construction of the wastewater plant upgrade and control project was completed in 1997.

Served as the manager of an environmental impact analysis on a 4-hectare property located in the Capital Federal District of Buenos Aires, Argentina. Work was performed as a preliminary response to using the property for development of a solid, sludge, and liquid waste treatment facility. All work was performed in accordance with Argentine Law 24.051. The waste treatment plant was a centralized location for the treatment and handling of liquid waste products from service stations and ships. Phase I–III design package materials were prepared for the waste treatment plant to remediate ship and service-station waste products. This was the first plant designed for the purpose of treating and recycling hazardous waste products in Argentina.

Served as the general manager in the application of a detailed environmental impact assessment on a 50-hectare former pharmaceutical manufacturing facility located in Buenos Aires, Argentina, in accordance with Argentine Law 24.051. The results of the investigation indicated that remedial actions were necessary. This work included the installation of a soil vapor extraction system to remediate acetone vapors using U.S. thermal oxidation equipment; the uncovering, decontamination, and removal of 11 underground storage tanks with combined capacity of over 575,000 liters; the performance of in-situ and ex-situ bioremediation of soil contaminated with kerosene through heavy fuel oil; the removal and repair of asbestos-containing materials; and the evaluation and maintenance of PCB-containing machinery. Ultimately, the site was sold. Those negotiating the sale used the environmental impact assessment and resultant remedial report to document and verify that environmental liabilities had been remediated and that value had been returned to the site.

Served as the general manager in the application of a detailed environmental impact assessment and feasibility study analysis for the purchase/sale of a 100-hectare former chlorine manufacturing facility located in Neuquen, Argentina, in accordance with Argentine Law 24.051. The results of the investigation indicated that remedial actions were required for a number of problem areas at the site. Mercury contamination was found at several locations where elemental mercury had contaminated the groundwater and soils beneath the site. This was compounded by the presence of vinyl chloride and dioxins. During the feasibility study analysis, a cut-off wall and water treatment system were designed to contain the groundwater contaminant plume within the site boundaries. Remedial costs were evaluated with respect to the total facility operational costs.

Directed the site remediation for a service station in Buenos Aires, Argentina. The remediation system included the installation of soil vapor extraction wells and the importation of thermal oxidizer equipment to treat soil vapors contaminated with gasoline, diesel, and kerosene at the site. All work complied with regulations established by the Dangerous Waste Law No. 24.051 of Argentina, and the Municipalidad de Buenos Aires.

Served as program manager and directed an extensive site assessment, soil sampling program, and groundwater monitoring network installation (100 samples, 48 borings, 12 wells, and 63 piezometers) at an ethylene dichloride waste management area at a chemical plant in Talcahuano, Chile (200 km south of Santiago). In the late 1970s and early 1980s, DNAPL (i.e., mixed chlorinated solvents, EDC, PCBs, vinyl chloride, dioxins) contamination was buried in shallow, near-surface pits. Site investigation and remedial action analyses were performed to determine the necessary remediation system. Several remedial options were evaluated, including incineration, thermal desorption, in-situ fixation, slurry wall and cap, groundwater treatment, landfill, and no action. In late 1995, the installation of a site groundwater containment system, slurry wall, and cap was approved and scheduled for construction in early 1996. Total estimated project value was $5,400,000. Remedial activities included the installation of approximately 2 km of slurry wall to a nominal depth of 25 m, surface water drainage controls, constructed site cap (both soil and asphalt), irrigation system, and groundwater control and treatment systems. The project was completed and the system was operational in early 1997.

Served as both project manager and geohydrologist while preparing the RFI work plan for sediments, soil, and groundwater investigations at The Dow Chemical Company in Freeport, Texas (Blocks A-41/A-42). The site investigation included the evaluation of three separate groundwater aquifers contaminated with two distinct DNAPLs (primarily EDC wastes with PCBs and dioxins in excess of 40,000,000 gal). The complex Gulf Coast site stratigraphy required extensive evaluation of the groundwater regime. Remedial options evaluation included placement of horizontal wells, interception trenches, large-bore DNAPL collection systems, and hydraulic barriers. Both human and ecological risk assessments were prepared in an integrated, proactive approach.

Managed the installation of a soil vapor extraction system at the Well 12A Superfund Site in Tacoma, Washington. The system operates through 22 wells at a maximum 3,000 ft^3 per minute, extracting VOCs and other chlorinated solvents from the subsurface. Constructed with the ability to control and monitor the soil gas extraction process from any configuration of the system, the gas treatment system involved filtering the hot soil gas for particulates, then cooling the gas and extracting the VOCs. The gas treatment system cycles were controlled with a programmable logic controller (PLC) system that determined valve opening and closure for each cycle. Responsible for constructing and optimizing the subsurface system, including input and calibration for a modular, 3-dimensional, finite-difference model. This was performed using a combination of model packages (VENTING, MOTRANS, MODFLOW). Used the flow model for assessment of conceptual design scenarios, estimation of capture zone and stagnation points, and evaluation of the capture zone with varying extraction rates and configurations.

Served as project manager for sediment dredging project associated with a dockside spill of ethylene dichloride (EDC). This work was performed at The Dow Chemical Company Plant A facility in Freeport, Texas, in the Brazos River Harbor area adjacent to the Intracoastal Waterway. The dense non-aqueous-phase liquid (DNAPL) was released while loading from dockside facilities to a barge. Dredging was implemented on an expedited schedule, and sediments were removed using a barge-mounted environmental clamshell dredge to barges for removal from the site. Both dockside and unloading facility worker health and safety were monitored continuously using both site-wide and personal air monitoring equipment. Site cleanup activities proceeded to completion on the expedited schedule with no health and safety issues.

Prepared a RCRA corrective measures study (CMS) for soil and groundwater investigation at The Dow Chemical Company in Pittsburgh, California. The site investigation included evaluation of shallow groundwater aquifers contaminated with arsenic, chromium, and lead, resulting in potential contamination of bay sediments. The complex San Francisco Bay site stratigraphy required extensive evaluation of the groundwater regime. Did preparatory work, including a statistical evaluation of soil and groundwater contaminant levels, prior to evaluating in-place closure. Cost analyses were prepared for appropriate waste management units.

Managed the RCRA facility investigation (RFI) that addressed the requirements noted in the RCRA Part B permit covering an inactive solvent recycling facility located outside Portland, Oregon. Because the permit was issued jointly by the Hazardous and Solid Waste Division of the Oregon Department of Environmental Quality (ODEQ) and the Region 10 office of the U.S. Environmental Protection Agency, the entire facility was treated as a single solid waste management unit. The permit required an RFI to be performed on the entire facility. Indoor and outdoor drum storage areas had been used for storing spent chlorinated solvents prior to reclamation within the onsite distillation unit, or transport to offsite hazardous waste management facilities for disposal. Leaks and spills from these areas had resulted in a large chlorinated solvent plume in the local groundwater system.

Evaluated extensive chlorinated solvent groundwater plumes at two separate locations in Burbank/North Hollywood, California. Groundwater evaluation included regional geology, groundwater pumping, reinjection, and treatment. Assisted with development of dual train stripping tower treatment system.

Assisted legal counsel in the preparation and evaluation of historical use practices, data analysis, data interpretation, report preparation, and regulatory interaction for a 1,600-acre former dynamite production plant. Performed a detailed analysis on the chemical and physical hazards present at the site, and documented remedial and physical cleanup actions. Ultimate use of the site included recovery of forest products, residential homes, public facilities, and a proposed golf course.

Managed and prepared the evaluation of injecting treated groundwater into an existing, saturated aquifer at the Shell Refinery in Carson, California, south of Los Angeles. The work included characterization (both quality and quantity) of the proposed injection water and the injection zone. Assessed potential chemical interactions between native and injected fluids.

Managed the site investigation, performed soil sampling, and documented findings in support of litigation for a property in Woodinville, Washington. Onsite contaminants resulted from poor materials handling processes that occurred on the upgradient, adjacent property. As a direct result of the findings, the upgradient property owners assumed liability and costs associated with remediation of contaminants on the property.

Managed the site investigation, performed sediment sampling, and documented findings in support of litigation for the Cedar River Delta in Lake Washington near Renton, Washington. The program was designed to evaluate the PCB and metals concentrations for the shallow, nearshore, lacustrine sediments. Contaminants resulted from multiple industrial activities associated with the poor materials handling processes that occurred on the upgradient, adjacent property.

Evaluated chlorinated solvent groundwater plumes at two separate locations in Burbank/North Hollywood, California. Groundwater evaluation included regional geology, groundwater pumping, reinjection, and treatment.

Prepared an expedited RI/FS for multiple potentially liable parties (PLPs) at a site where free-phase gasoline was distributed in subsurface soil over a 20-acre area. Designed the work plan to provide data of sufficient quality and quantity to evaluate remedial options and support human health risk assessment. Reports were prepared in a limited time period to avert a probable enforcement order by Ecology (State of Washington). Work included preparation of a multi-media work plan and human health risk evaluation that required substantial interaction with multiple PLPs and negotiation with Ecology.

Managed an MTCA-based site assessment and investigation for the Port of Seattle at the former Coast Guard Facility along Salmon Bay in Seattle, Washington. Work included the installation of site-wide groundwater wells, soil sampling, storm drain sediment sampling, and aquatic sediment sampling. Integrated the data into a conceptual model of fate and transport of contaminants at the site based on former industrial practices at the site. The information collected at the site was integrated into an ecological and human health risk assessment that was used to direct potential remedial alternatives.

Served on retainer for litigation in support of analysis of site contamination (soil, sediments, surface water, and groundwater) at a historical industrial complex and municipal landfill. The site was located in the sensitive estuarine environment adjacent to Grays Harbor, Washington. Prepared written materials and assessments prior to litigation. To the client's satisfaction, the bankruptcy court allowed the property to be abandoned. This allowed the client to settle debt and remove one of the longest held bankruptcy cases in the U.S. 9th District Court.

Served as program manager for the closure of Class V injection wells under EPA Order on Consent at seven sites for a major oil company. Project involved substantial interaction with the client and Ecology, to initiate and maintain this program under rigorous MTCA regulatory and time constraints. This included work plan preparation, coordination of field and laboratory activities, data review and analysis, and closure report preparation. Field operations consisted of excavation and removal of the injection wells, hollow-stem auger soil boring, installation of monitoring wells, and environmental sampling.

Served as the program manager for Phase I and II underground storage tank site investigations for a major oil company. The work included installation, operation, and maintenance of groundwater treatment, vapor extraction, and air sparging systems; tank removal; and site closure at more than 50 sites.

Managed a site assessment work plan and sampling program for a former lumber mill and municipal landfill site in the estuarine environment near Grays Harbor, Washington. Coordinated all field work, including collection of soil, surface water, sediment, and subsurface samples for detailed metals and organic contaminant analyses. Based on human and ecological health, developed Washington State MTCA cleanup standards.

Prepared soil investigation and hydrogeologic study plans for the RI/FS at the Alkali Lake site in eastern Oregon. The site was used for storage and disposal of chemical wastes. The site is situated in a non-draining basin and was contaminated with process sludges that were stored in barrels at the site from the manufacturing of pesticide (2,4-D).

Performed a full-scale waste treatability evaluation, including column leaching tests, batch tests, and pre- and post-treatment chemical analyses. The results allowed the client to decide against proceeding with this treatment alternative because of the unacceptable lead concentrations in the waste filter cake. The primary environmental matrix evaluated was flue dust.

Managed multiple RI/FSs and engineering evaluation/cost analyses (EE/CAs) to evaluate soils, air, vegetation, surface water, and groundwater at a 20-mi^2 former smelter site near Anaconda, Montana. Sampling included placement of 27 wells, collection of approximately 10,000 soil samples, analysis of surface drainage and erosion, installation of an air monitoring network, and conduct of phytotoxicity. Data were integrated into an ArcInfo® geographic information system for rapid review and analysis, including evaluation of potential offsite transport of specific contaminants in surface soils using physiographic conditions and the modified universal soil loss equation, groundwater modeling, kriged summarization of three-dimensional soil contaminant distributions, groundwater modeling, and statistical summarization of contaminant distributions for evaluation of human health risk and contaminant transport and fate. Extensive use of statistical methods provided the client with focused revision of the EPA-mandated sampling programs into manageable and cost-effective forms.

Managed, designed, and prepared a work plan and QAPP for a flue-dust reclamation pilot test to render RCRA waste less hazardous while reclaiming metals. Performed all test process sampling, QA/QC, and data analysis for the project report.

Served as the site data coordinator for natural resource damage assessment for a large CERCLA mine site in the western United States. Data included over 250,000 entries of soil, water, vegetation, and miscellaneous chemical information.

Managed an EE/CA for two smelter sites near Anaconda, Montana. Prepared work and site safety plans while coordinating field work.

Evaluated the distribution and regulatory implications of mine tailings throughout a former mill in New Mexico. The regulatory evaluation included country-wide evaluation of disposal options and action levels for various metals contaminants. Prepared and reviewed fate and transport analysis of arsenic, cadmium, and lead in surface and groundwater. Some of the work included a statistical evaluation of the spatial distribution of surficial soil with respect to surface drainage patterns. Also analyzed regulations relating to potential cleanup standards and guidelines.

Managed preparation of a work plan for site remedial investigation of air, contaminant sources, soils, surface water, groundwater, geology, hydrostratigraphy, and public health at Smelter Hill, Anaconda, Montana.

Prepared the hydrologic assessment of contaminant transport from the 58-acre waterfront site inhabited by McCormick & Baxter Creosoting Co. between 1944 and 1991. Site work included evaluation of NAPL flow paths to the Willamette River, and PCP and PAH contamination in the uplands and river sediments.

Prepared a site geohydrologic evaluation for a RCRA site assessment and compliance monitoring evaluation at a hazardous waste site in Cody, Wyoming.

Prepared a soil, surface water, and geohydrologic analysis of a tidally influenced hazardous waste site (RCRA) at a timber treating facility near Olympia, Washington. Cascade Pole Co. wood treatment facilities operated at the site from 1957 to 1986. Similar site operations dated back to 1939. The site was located on Budd Inlet in Olympia, Washington, and the primary contaminants were creosote and pentachlorophenol.

Assisted in geologic and hydrostratigraphic evaluation of a site for a NOAA natural resource risk assessment project in Tampa Bay, Florida. Evaluated upland sites as potential contaminant source areas for estuarine sediments.

Prepared a site hydrological model and contaminant transport analysis for the tidally influenced 3,780-acre site located on the east side of Bainbridge Island, in Central Puget Sound, Kitsap County, Washington. The site consisted of an inactive 40-acre wood-treating facility adjacent to the 500-acre Eagle Harbor. From 1905 to 1988, wood-treating operations were conducted on the southeast shore, involving pressure treatment with creosote and pentachlorophenol.

Prepared a site geophysical investigation and reconnaissance survey work plan for a CERCLA mine site at Bunker Hill, Idaho. This included an evaluation of a series of valleys with very tight configurations and fill sediments for hydraulic connectivity.

Prepared sediment sampling protocols following PSDDA protocols. Using gravity coring devices and bucket samplers, collected Commencement Bay sediment samples. Prepared quantitative analytical results, integrated these results into the basin-wide database, and compared relative toxicity based on chemical mix.

Prepared a siting analysis for dredge disposal materials collected in San Francisco and Oakland Bays. The analysis included evaluation of upland, nearshore, and deep-water disposal options for the dredge materials. Used standards of analysis, environmental impact, and site characteristics to evaluate the relative impact of disposal at each site.

Wrote a technical memorandum pertaining to potential remedial technologies for in-situ amelioration of inorganic contamination. Also provided technical and cost reviews of soil solidification, deep soil mixing, and in-situ vitrification.

Prepared a site evaluation for potential natural resource damage claims at a metal plating/ anodizing facility on Long Island, New York. Evaluated upland sites as potential contaminant source areas for estuarine sediment loading.

Managed field and laboratory investigation of trace-element contamination in surficial soils at an 8.5-mi^2 site in Butte, Montana. Prepared work plan and QA/QC project plan, performed statistical analysis of data, and prepared project reports. Performed sampling based on a statistical approach to minimize the total number of samples while maximizing the statistical significance of grouped samples. Sample groups included vegetable gardens, flower gardens, playgrounds, schools, private-residence yards, waste piles, street sweepings, vacant lots, and hockey rinks. Approximately 200 locations were sampled.

Coordinated preparation of a smelter RI/FS master investigation report, including fate and distribution of contaminants in all media. Performed geological and reconnaissance investigations for a 20-mi^2 site.

Coordinated preparation of the Mill Creek, Montana, RI/FS on a compressed time schedule. Primary responsibilities included evaluation of geology, hydrostratigraphy, and hydrology; field sampling for soils; planning and implementation of bench and pilot studies; and reconnaissance surveys.

Prepared maps and documented potential remedial action operable units within the Clark Fork River drainage in southwest Montana.

Managed the preparation of the Butte, Montana, RI/FS work plan, including public health impacts; air, soils, surface water, and groundwater site reconnaissance; historical mining practices; geologic background evaluation; and hydrological investigations.

Prepared statistical summaries and data organization for preparation of an endangerment assessment for Mill Creek, Montana.

Participated in field sampling efforts in the Gulf of Mexico, southern California, Alaska, and the Puget Sound for feasibility studies and petroleum hydrocarbon distribution and mapping.

Served as a field geologist for a deep, continuous-borehole geological and geo-physical logging operation in Loving County, Texas. This included local and regional stratigraphic correlation, aquifer definition, and subsurface geologic properties.

Served as project stratigrapher for numerous offshore hydrocarbon exploration cruises in Alaska and the U.S. West and Gulf Coasts. Coordinated real-time mapping activities of hydrocarbon potential. These surveys included reflection and refraction profiling designed to evaluate near-surface potential geohazards and deep structural and stratigraphic sequences. Also designed and evaluated geophysical borehole programs, including sonic velocity, resistivity, gamma ray, induction, and spontaneous potential.

Professional Affiliations

- Freestone Council of the Big Hole River Foundation (charter member)
- American Association of Petroleum Geologists
- Society of Petroleum Engineers

Deposition and Trial

Charles A. Burnia, et al. v. Fluor Corporation, et al., Dustyn Dowd and Toby Marler et al. v. Fluor, Corporation, et al., Alicia Politte, et al. v. Fluor Corporation, et al. Cause Nos. 052-9605, 012-8639, 052-10299. Division No. 8, Missouri Circuit Court of the Twenty-Second Judicial Circuit, City of St. Louis. Expert report submitted on June 3, 2013. Deposition on June 13, 2013.

> *Charles A. Burnia, et al., minors, by and through their Next Friend, Melissa Burnia, Plaintiffs, Cause No. 052-9605 v. Fluor Corporation, et al.* Division No. 8, Missouri Circuit Court of the Twenty-Second Judicial Circuit, City of St. Louis.
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> *Dustyn Dowd, a minor, by and through his Next Friend, Lisa Dowd, and Toby Marler, a minor, by and through his Next Friend, Regina Marler, Cause No. 012-8639 v. Fluor Corporation, et al.* Division No. 8, Missouri Circuit Court of the Twenty-Second Judicial Circuit, City of St. Louis.
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> *Alicia R. Politte, et al., minor, by and through their Next Friend, Deana Chipman, Plaintiffs, Cause No. 052-1029 v. Fluor Corporation, et al.* Division No. 8, Missouri Circuit Court of the Twenty-Second Judicial Circuit, City of St. Louis.
>
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Vornado Realty Trust, et al., against, Marubeni Sustainable Energy Inc., et al. Case No. 08-CV-4823 (WFK) (JO). James Orenstein, Magistrate Judge, United States District Court, Eastern District of New York. Expert report submitted on December 18, 2012. Rebuttal expert report submitted on April 8, 2013.

PCS Nitrogen, Inc., Plaintiff, v. Ross Development Corporation; T. Heyward Carter Jr.; Grayson G. Hanahan; William O. Hanahan, III; Katharyne H. Rike; Estate of G.L. Buist Rivers, Jr.; Mikell R. Scarborough; C. Cotesworth Pincney and T. Heyward Carter, as Co-Trustees of the Trust of William O. Hanahan Jr.; Anne Hanahan Blessing; Donald Buhrmaster, III;

Eleanor W. Carter; Margaret H. Carter; Elizabeth H. Clark; Maria Grayson-Metaxas; Buist L. Hanahan; Elizabeth A. Hanahan; Francess G. Hanahan; Mary Ross Hanahan; Muriel R. Hanahan; Roger Parke Hanahan, Jr.; Grayson C. Jackson; Oriana H. Kirby; and Jeanne Deforest Smith Hanahan, Defendants. Case No. 2:09-CV-3171-MBS, First Amended Complaint in the United States District Court, District of South Carolina, Charleston Division. Expert report submitted on March 9, 2011.

Joseph A. Pakootas, and individual and enrolled member of the Confederated Tribes of the Colville Reservation; Donald R. Michel, and individual and enrolled member of the Confederated Tribes of the Colville Reservation, Plaintiffs-Appellees and State of Washington Plaintiff/Intervener, v. Teck Cominco Metals, Ltd., a Canadian corporation, Defendant-Appellant. Expert report submitted on January 14, 2011. Deposition on April 7, 2011.

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INTALCO Aluminum Corporation v. Central National Insurance Company of Omaha, et al., Case No. 06-2-01842-3 In the Superior Court of the State of Washington in and for the County of Whatcom. Expert report for the Intalco Aluminum Smelter Site, Ferndale, Washington and Expert report on Behalf of Century Indemnity Company submitted on June 12, 2009. Rebuttal submitted on July 10, 2009. Deposition on August 25, 2009. Declaration in support of Century defendants motion for summary judgment, October 6, 2009.

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Raymond Howard and Phyllis Jean Howard, individuals and Western Asphalt, Inc. and Illinois Corporation, Plaintiffs, v. GTE Service Corp., a New York corporation, and EEI Holding Company, Inc. an Illinois corporation, d/b/a Sullivan Electric Company, Defendants. In the Circuit Court of the Seventh Judicial Circuit Morgan County, Illinois, Case No.: 00-L-8. Expert Report for the Western Asphalt Property, Jacksonville, Illinois submitted on December 12, 2008. Deposition on July 10, 2009.

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City of Tacoma v. GAIC, U.S. District Court, Washington, Case No C97-5504RJB, Expert declaration, October 5, 2005; Mediation held in January 2006; trial scheduled for April 2006: Case successfully mediated in March 2006.

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City of Tacoma, a Municipal Corporation and Jack Morris v. Santa Fe Pacific Corp. a Delaware Corporation et al., Superior Court of the State of Washington in and for the County of Pierce, Case No. 98-2-08932-1, expert report, August 11, 1999.

Exhibit B

Documents and Information Reviewed

Documents and Information Reviewed

Anchor QEA. 2010. Final removal action work plan - time critical removal action -San Jacinto River waste pits superfund site. November 2010. Prepared for U.S. EPA, Region 6, on behalf of McGinnes Industrial Maintenance Corporation and International Paper Company. Anchor QEA, LLC, Ocean Springs, MS.

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HGAC 2006 (1 ft)-6159_2006 (Aerial photo)

HGAC 2008 (1 ft)-6159_2008 (Aerial photo)

Historical Images-TxDOT_04-16-1980_23-574 (Aerial photo)

Historical Images-TxDOT_10-9-1989_5-102 (Aerial photo)

Historical Images-TxDOT_12-2-1986_20-772 (Aerial photo)

Historical Images-USDA_2-15-1973_273-88 (Aerial photo)

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Historical Images-USGS_10-25-1962_1-259 (Aerial photo)

Historical Images-USGS_2-23-1976_2-341 (Aerial photo)

Historical Images-Wallace_02-21-1969_17 (Aerial photo)

Integral Bates No- 362916 (Aerial photo)

Integral Bates No- 362917 (Aerial photo)

Integral Bates No- 362918 (Aerial photo)

Integral Bates No- 362919 (Aerial photo)

Integral Bates No- 362920 (Aerial photo)

Integral Bates No- 362921 (Aerial photo)

Integral Bates No- 362922 (Aerial photo)

Integral Bates No- 362923 (Aerial photo)

Integral Bates No- 362933 (Aerial photo)

Integral Bates No- 362934 (Aerial photo)

Integral images-01_1962 (Aerial photo)

Integral images-06_1970 (Aerial photo)

IP Bates No-IP0391072 - HGAC Aerials 2004 (Aerial photo)

IP Bates No-IP0391073 - HGAC Aerials 2002 (Aerial photo)

IP Bates No-IP0391074 - HGAC Aerials 2006 (Aerial photo)

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IP Bates No-IP0391081 - NAIP Aerials Undated (Aerial photo)

IP Bates No-IP0391082 - Historical Aerials 4-16-80 (Aerial photo)

IP Bates No-IP0391083 - Historical Aerials 10-9-89 (Aerial photo)

IP Bates No-IP0391084 - Historical Aerials 12-2-86 (Aerial photo)

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NAIP TOP-TOP0809_50cm_2995_16_3_NC_14012009 (Aerial photo)

NAIP TOP-TOP96_1M_CIR_2995_16_3 (Aerial photo)

Subsidence Documents

1905 map pieced together with Koenig em

1906-2000 subsidence map

Anchor. (undated). Area subsidence history. Figure. Anchor QEA.

Appendix A - Maps and aerial photographs of the San Jacinto River at I-10 (050415 letter to TCEQ)

Draft summary of Dioxin/PCB TMDL Stakeholder meeting on August 17, 2011

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701105 TPWD-Chrisley Dredg Permit Hearing Mins

701109 TPWD Request for Study of SJR Dredging

710205 TPWD Report on Study of Dredgin SJR

710212 TPWD Hrg Mins Deny Parker Bros Permit

710212 TPWD Ntc re study and dredge SJR limits

711217 TPWD Ntc re Horton Dredge App (HW Notes re I-10)

720203 TPWD Notice re No Dredge Mouth SJR to I-10

720203 TPWD Ntc-Study concludes No Dredge SJR

720530 TPWD Ntc Parker Bros Dredge Permit Hearing

740820 TPWD Hrg Mins on Paker Bros Permit

740830 TPWD-Parker Bros Dredg Permit Hearing Mins

750728 Parker Bros Ltr for Dredg Permit App

800731 TDWR Ltr to Jack Roberts re Permit App

840831 USFishWildlife Ltr to ACOE re HIT Permit

890118 Envl Assessmt on HIT Permit 15472(02)

920106 Ltr to TPWD re ParkrLaFarg Permit dredge I-10

920218 USFishWild to ACOE re ParkrLF prmt Subsidence

920604 TPWD Ltr History 70s Dredge Ban

920621 Chron Article on HIT dredge permit

920708 TxLandComm Obj ACOE PrkrLF Permit

920723 TxLandCommr to TPWD obj PrkrLF permit

920807 SJR Letter to Chair of TPWD re Paker Permit

920807 SJRA Obj to TPWD re PrkrLF permit grant

920818 Chron Dredgin Blamed Yard Cave In

920821 SJRA ltr to TPWD protest Parker Permit

920922 TWPD Ltr backgrd re PrkrLF permit

920927 Map Plans for HIT Permit

920928 SJRA Ltr TPWD overview river issues

921122 Chron Battle Lnx Dredg Ban (DIOXIN)

921130 Hstn Audobon Ltr to TPWD re dredging ban

921207 TPWD to TWC re dredge ban hearing

921208 BT Sun- Dredging Ban Hearing

921209 GBA Statement at Dredg Ban HRG

921209 SJRA Dredg Ban Statement-good info

921214 TPWD to ACOE re Proposed 3yr Ban SJR

921214 TPWD to CongrMan re TPWD Hrg-good info

921221 TPWD Ltr SenBentsen inform Hrg Dredg Ban

930120 ACOE to TPWD re Proposed DredgBan

930505 Parker Bros Dredging Settlement

960927 ACOE ltr to HIT re Permit 19284(2)

980108 ACOE Inv Report MegaSand for HIT